Functional properties of marginal starches from South-East Asia

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Cassava and Starch Technology Research Unit (CSTRU)

Quality control of cassava starch production in Thailand

Diversification of application for cassava starch:
- Physical and chemical modifications
- Bioethanol
- Bio-plastics

Valorization of by-products: Fibers

Work on other starches

Introduction

Roots and tubers represent a highly diverse source of starch but many crops remain underutilized for agro-industries, with production only at small scale for local use.

Few studies are available with a systematic characterization of the different types of starch in South-East Asia. This study undertakes to explore physicochemical and functional characteristics of several of these starches, using the same set of analytical techniques and experimental conditions.

Rationale: Identify specific properties, particularly in model food systems, to demonstrate starch potential as food ingredients and encourage the development of economic activities related to production and use. Focus on food applications because these starches are more expensive to produce than cassava or corn, so applications need to be high value added to cover the cost of production.

Tropical starches

- Canna (x2)
- Mungbean (x2)
- Sago
- Kudzu
- Taro (x2)
- Yam bean
- Sweet potato
- Potato
- Cassava (x3) + Rice & Maize

Tropical starches: Roots and Tubers (1)

Cassava

Canna

Kudzu

Sweet potato

Potato

Taro

Yam Bean

Tropical starches : Other crops (2)


Sago

Mung Bean

Rice

Maize

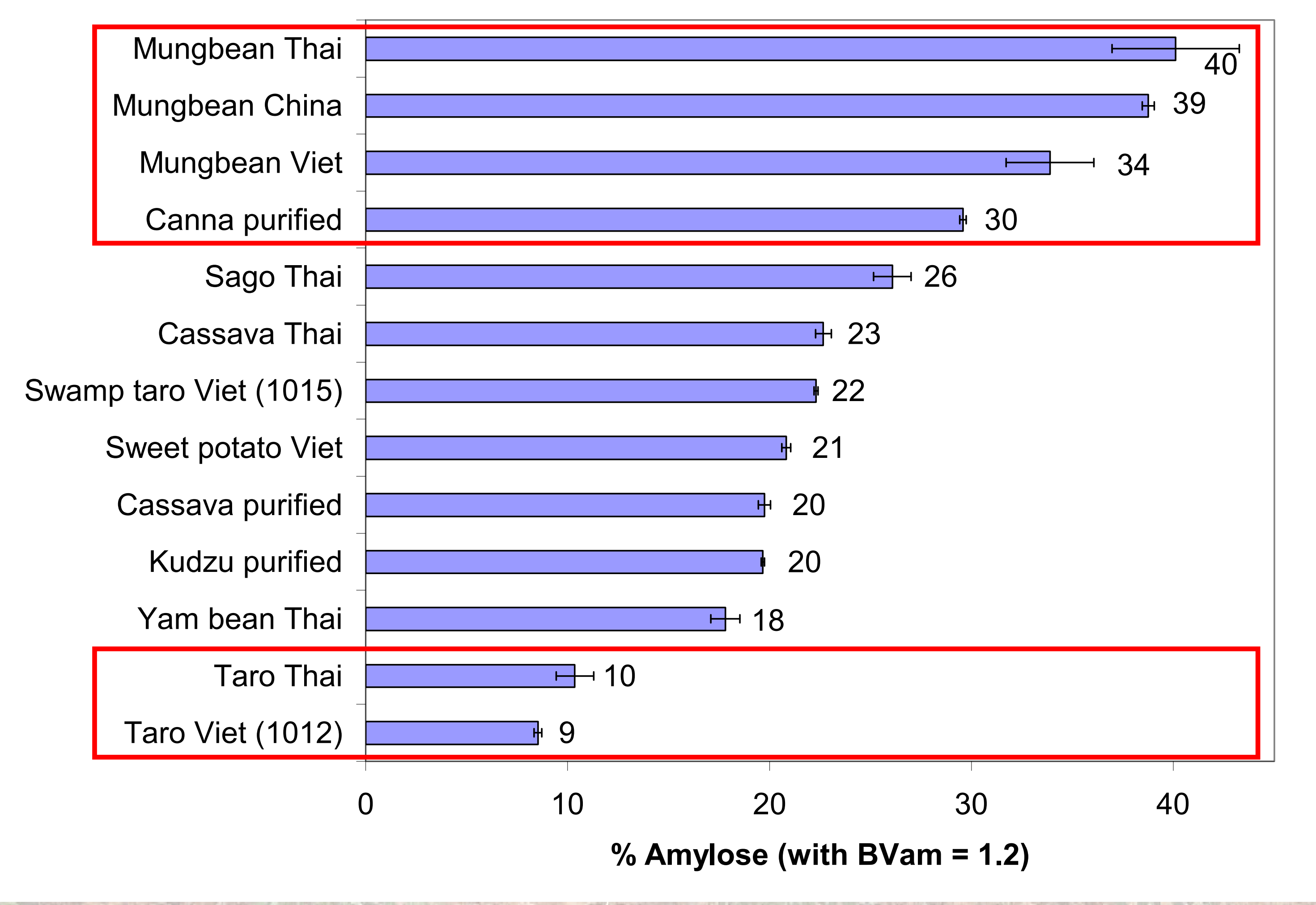
Starch source and composition

Starch extraction at lab scale (HUT / IPH in Vietnam; KU / CSTRU in Thailand)
Washing, peeling, cutting, crashing, filtering, collecting precipitate, air drying.

Starch source	**Origin**	**Lipid (%)**	**Nitrogen (%)**	**Ash (%)**
Manihot esculenta (Cassava)	Vietnam	**0.45**	0.014	0.02
Canna edulis ker (Canna)	Vietnam	0.31	0.014	0.23
Vigna radiata (Mungbean)	Vietnam	0.38	0.021	0.06
Colocasia esculenta (Taro)	Thailand	0.20	0.020	0.11
Pachyrhizus erosus (Yam Bean)	Thailand	**0.16**	0.013	0.03
Metroxylon sagu (Sago)	Thailand	0.17	0.021	0.32
Pueraria lobata (Kudzu)	Vietnam	0.39	0.023	0.10
Ipomoea batatas (Sweet Potato)	Vietnam	0.40	0.022	0.11
Solanum tuberosum (Potato)	Vietnam	0.25	-	0.44

Low lipid content (<1%). Extraction at lab. scale or purchase if commercially available

Amylose content (Blue value method)



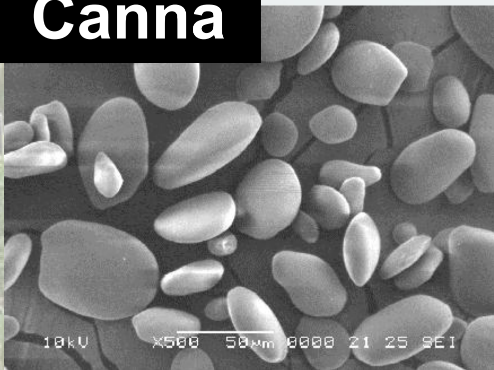
Range
10-40%

%AM = [BV(starch) - BV(ap)] / [BV(am) - BV(ap)] x 100
BV = Blue Value = Absorbance at 680nm (Takeda et al., 1983).

Morphological properties (SEM)

x2000

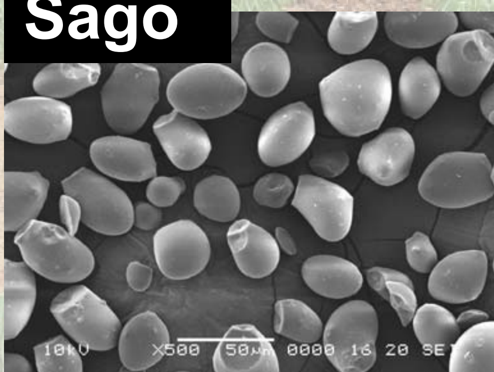
Canna



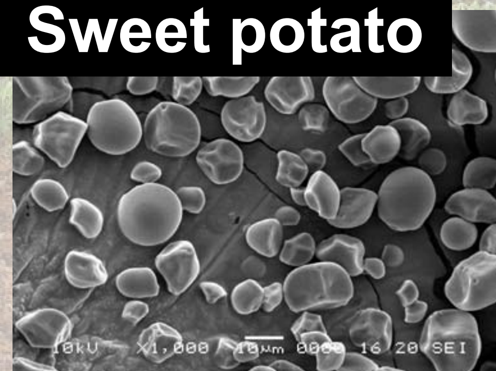
Mungbean

Yam Bean

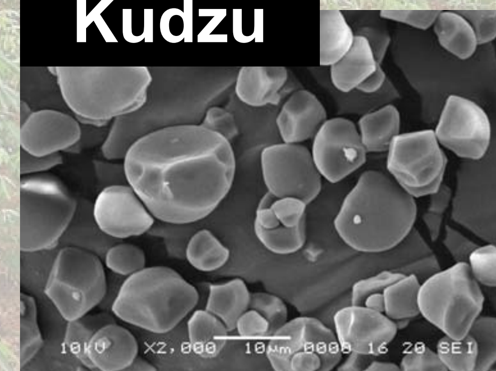
Sago



Sweet potato

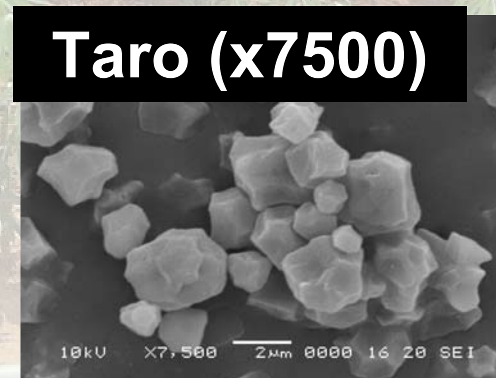


Kudzu



Cassava

Taro (x7500)



x500

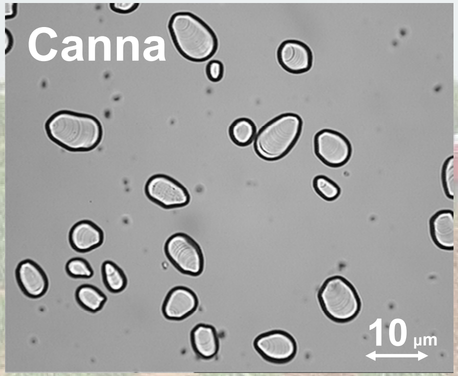
x1000

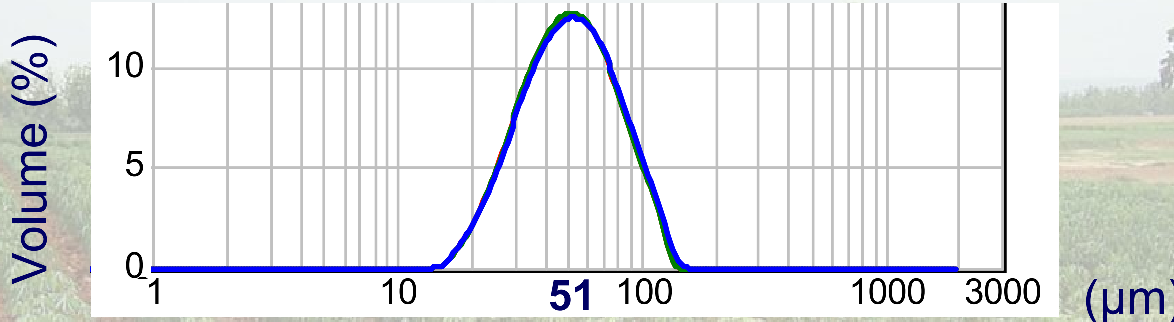
Compare with
Jane et al., 1994

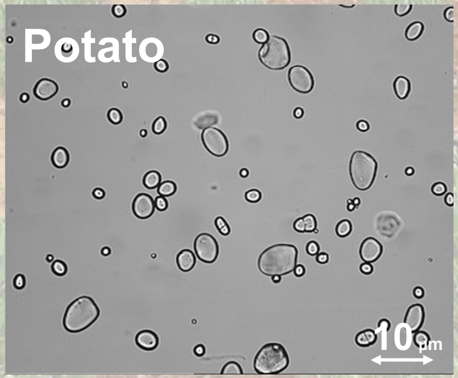
Morphological properties (1)

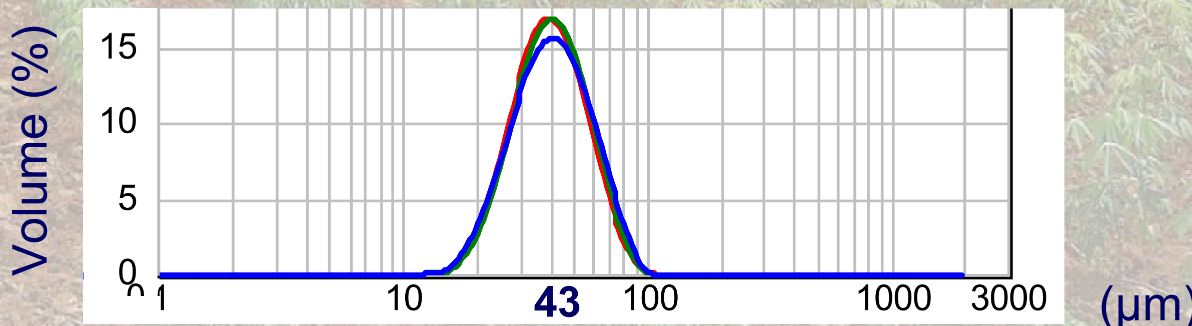
Light microscopy

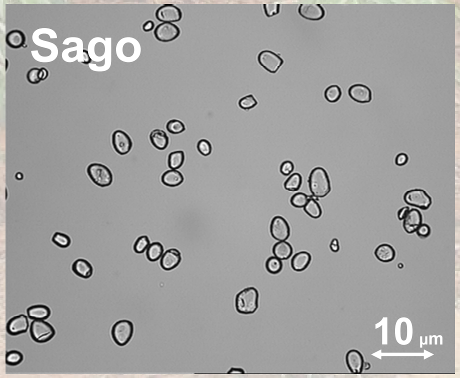
Granule size distribution (Laser diffraction)

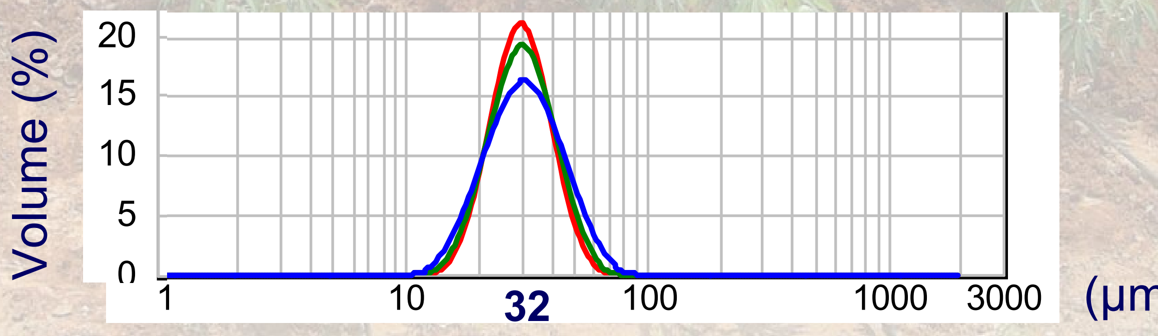






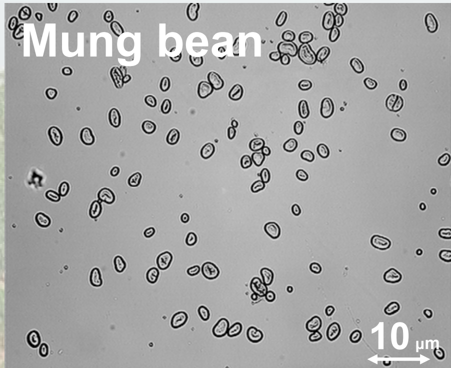


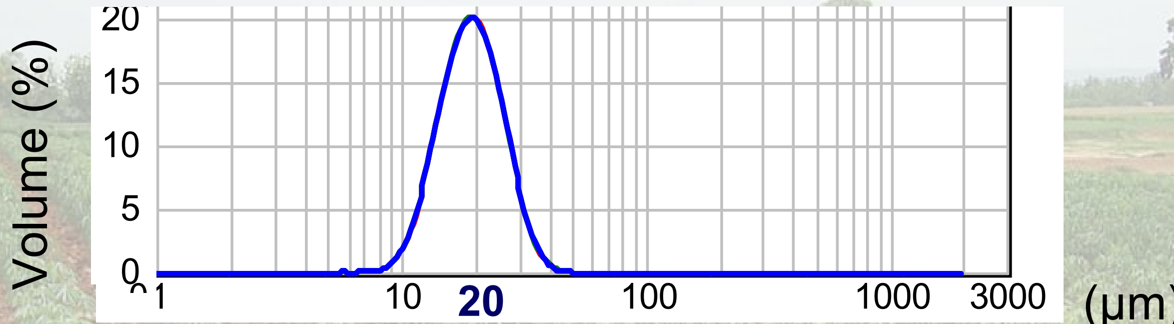


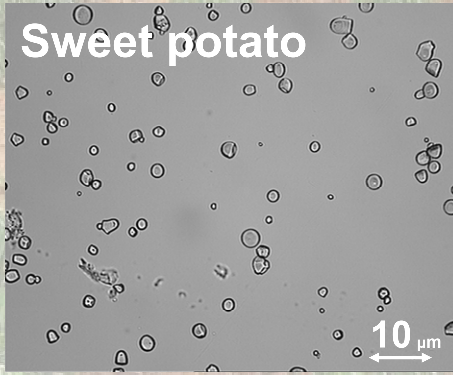


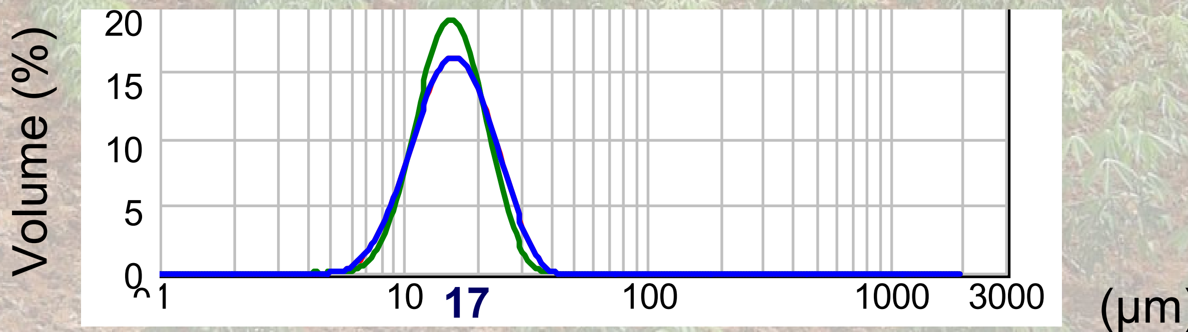
Morphological properties (2)

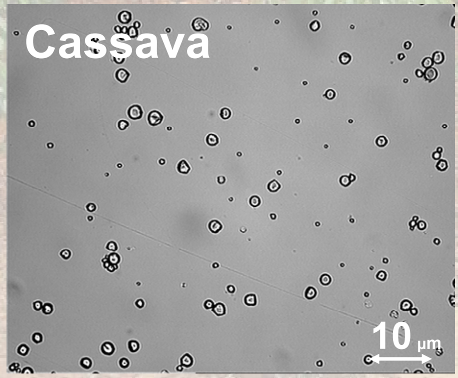
Light microscopy | Granule size distribution (Laser diffraction)

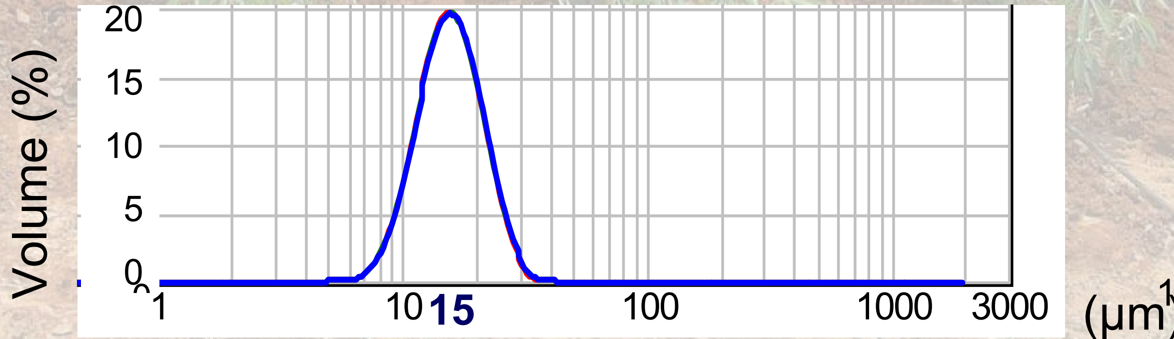








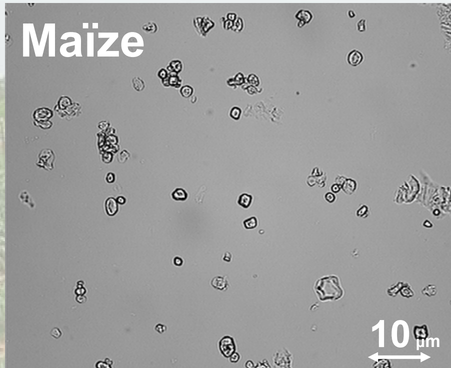


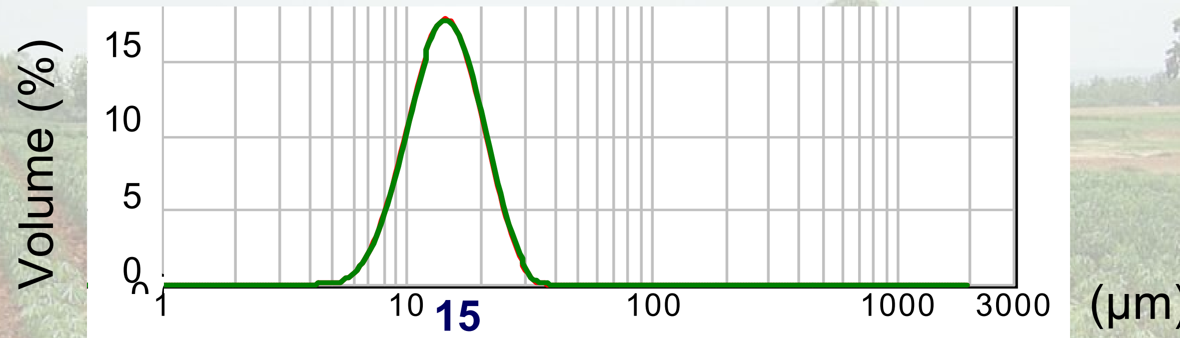


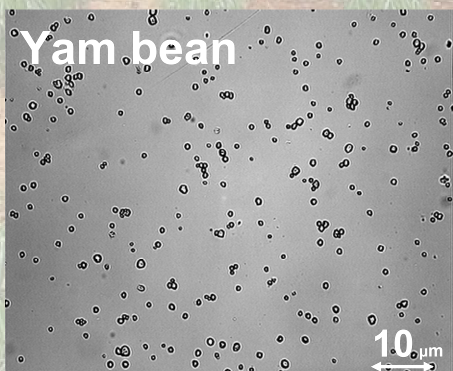
Morphological properties (3)

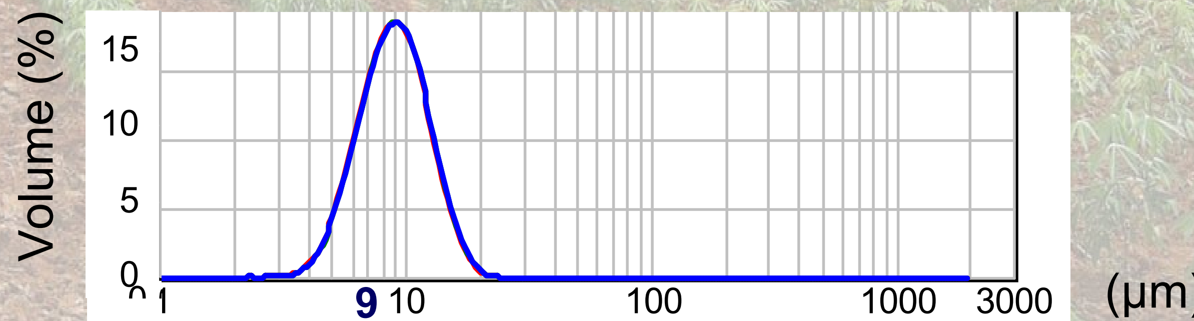
Light microscopy

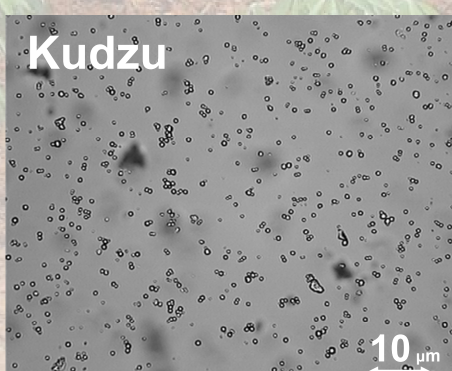
Granule size distribution (Laser diffraction)

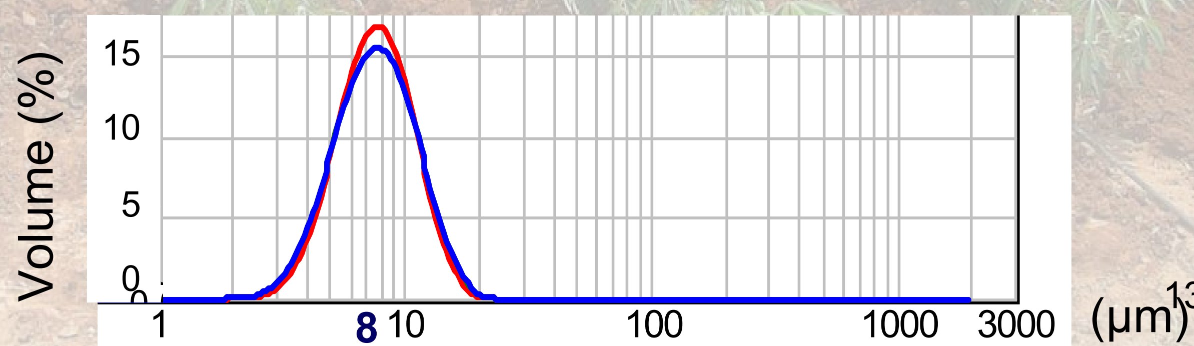






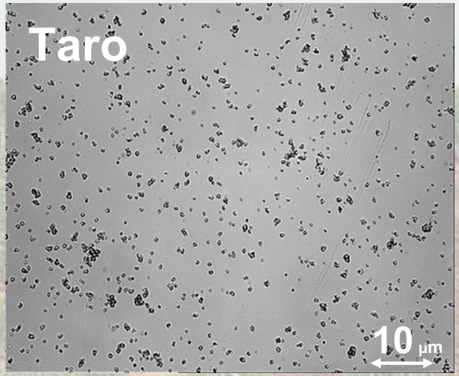




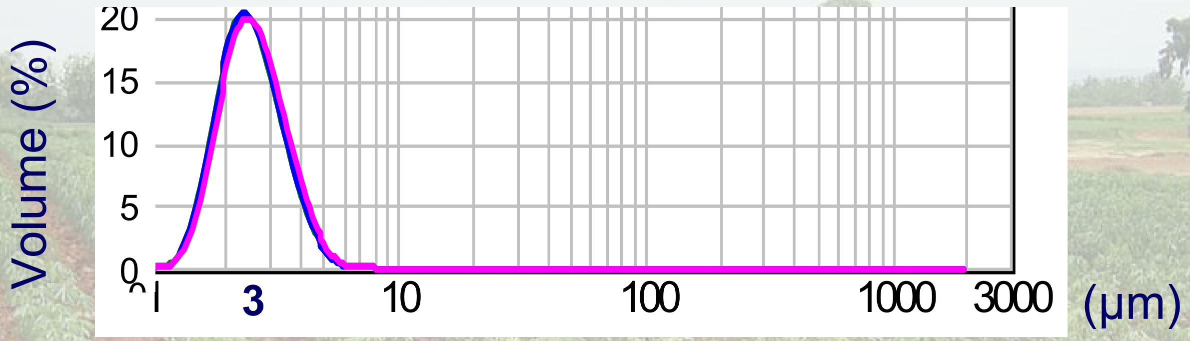


Morphological properties (4)

Light microscopy



Granule size distribution (Laser diffraction)



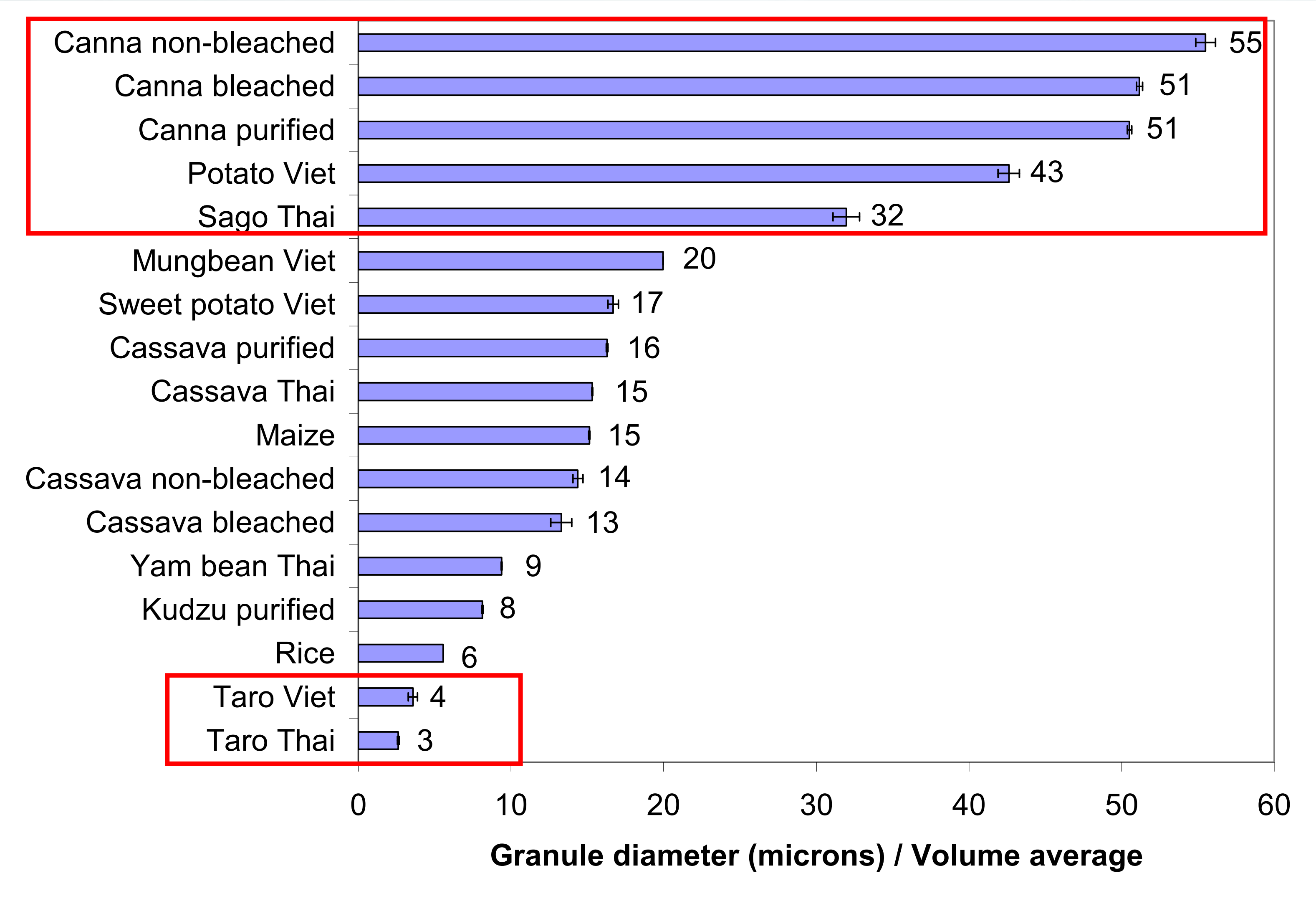
Starch source	D[4,3] (µm)	$d_{(0.5)}$ (µm)
Canna	55.5	50.9
Potato	42.6	40.3
Sago	32.0	30.5
Mungbean	20.0	19.2
Sweet Potato	16.7	15.8
Cassava	16.3	15.7
Maize	15.1	14.4

Starch source	D[4,3] (µm)	$d_{(0.5)}$ (µm)
Yam Bean	9.4	9.0
Kudzu	8.1	7.7
Rice	5.6	5.2
Taro	2.6	2.5

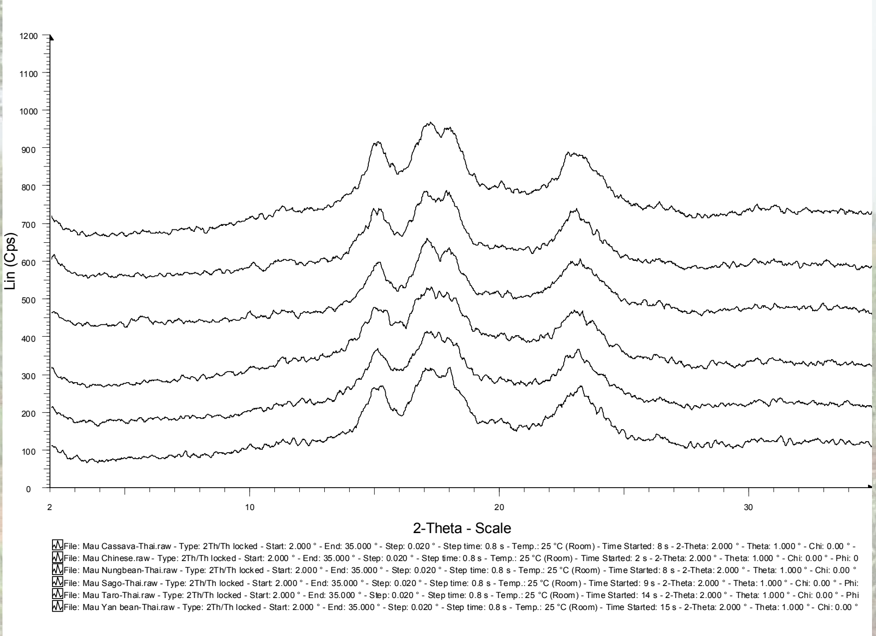
Most R&T starches are simple granules

Granules' shapes: oval, spherical, polygonal, irregularly shape

Average granule size



X-rays



Yam bean Thai – A

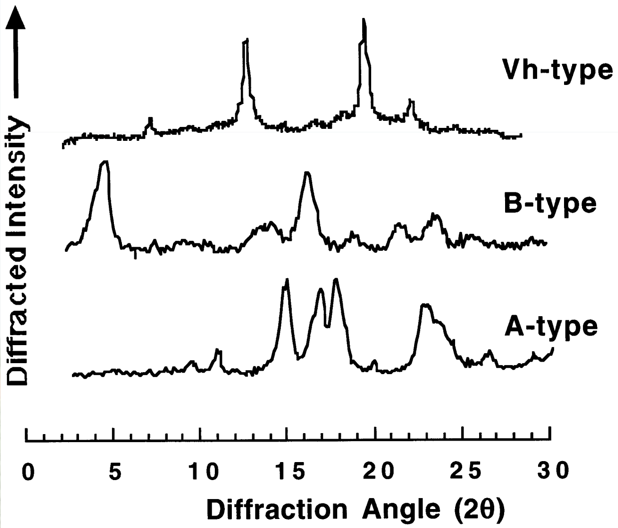
Taro Thai – A

Sago Thai – A

Mungbean Thai – C

Mungbean China – C

Cassava Thai – A

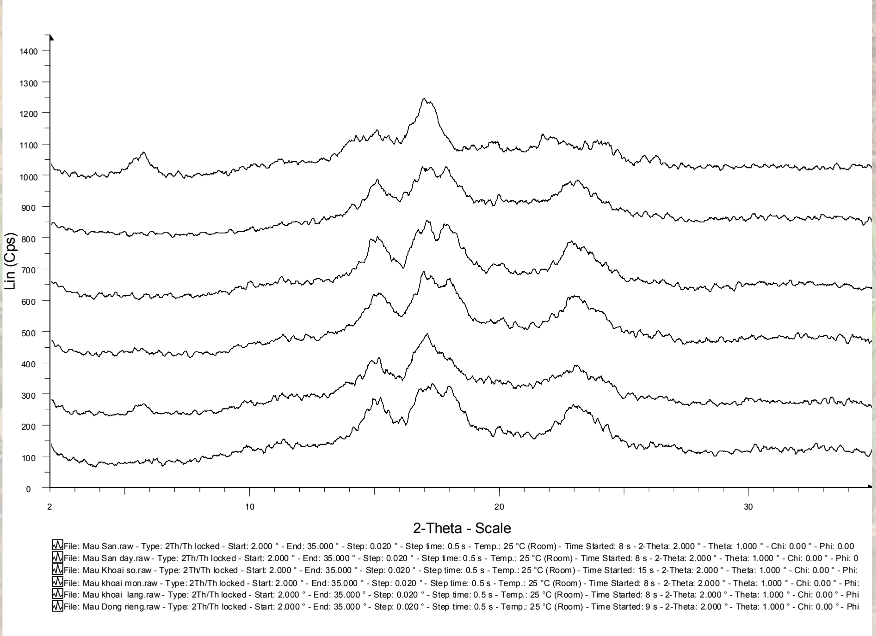


Buléon et al., 1998

A-type: Peaks at 15, 17, 18, 23°

B-type: Peaks at 5, (13), 16, 22, 24°

Different studies, different types of crystallinity (Zobel, 1988; Hung et al., 2005).



Canna Viet – B

Sweet potato Viet – A

Swamp taro Viet – A

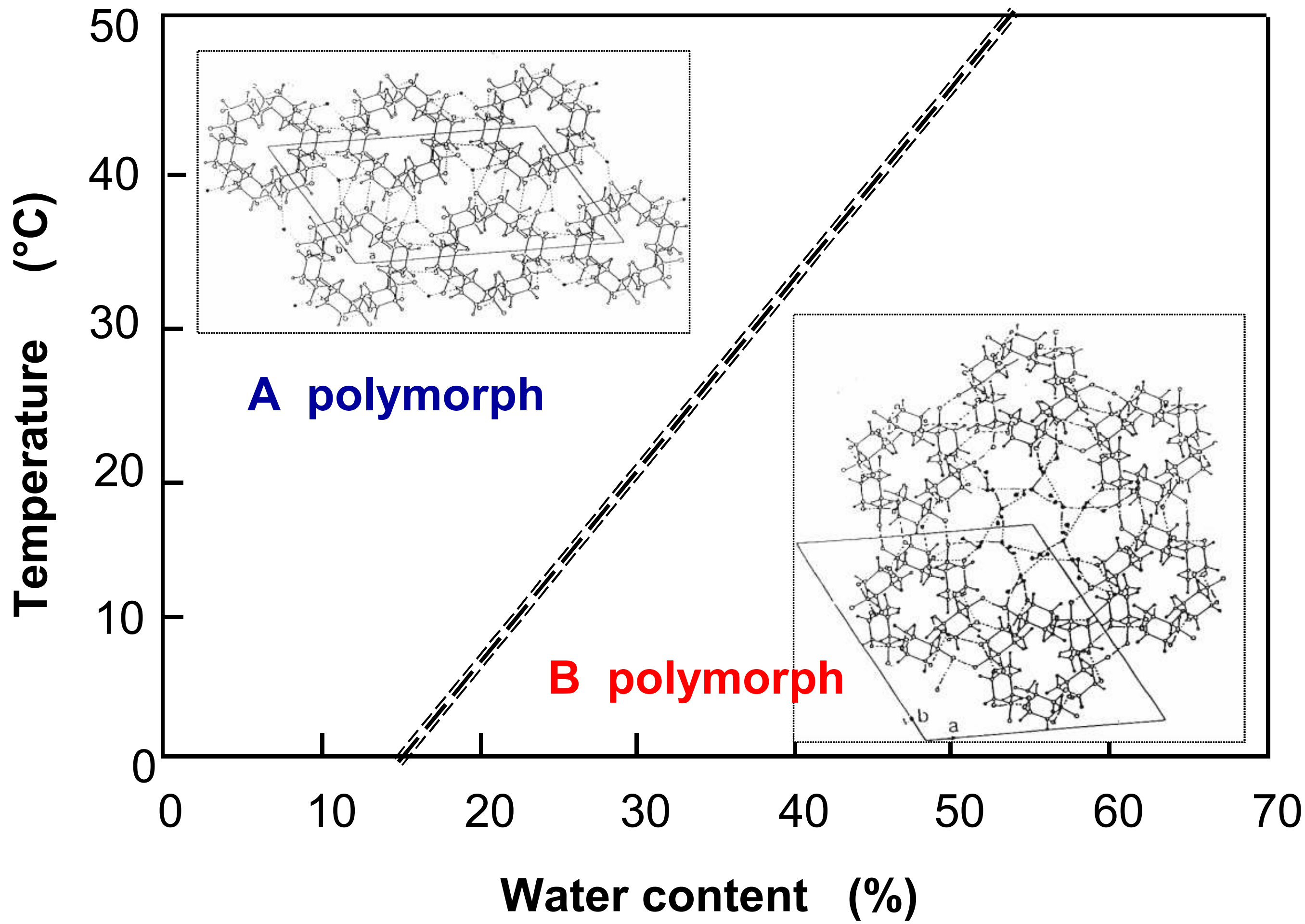
Taro Viet – A

Kudzu Viet – B

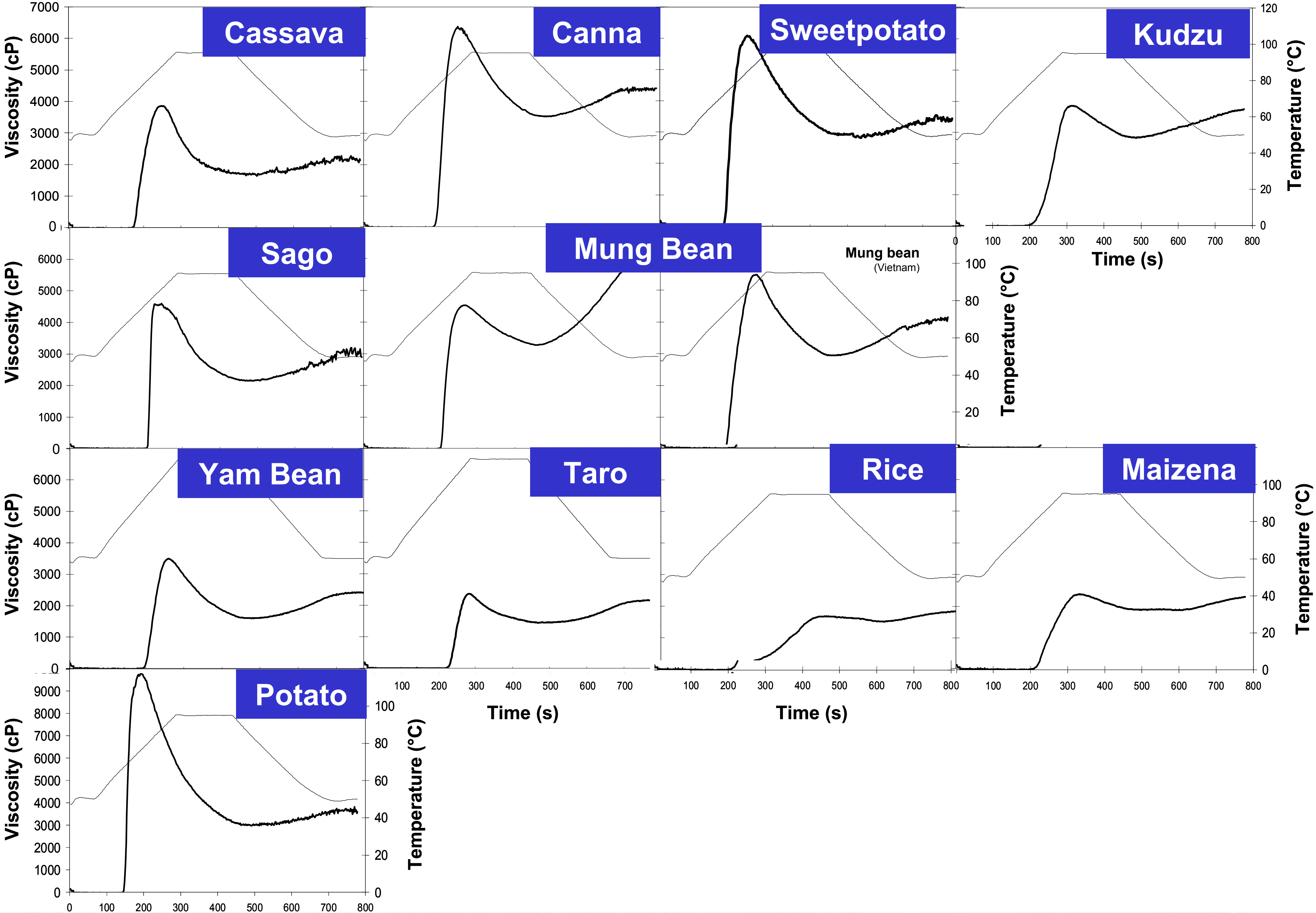
Cassava Viet – A

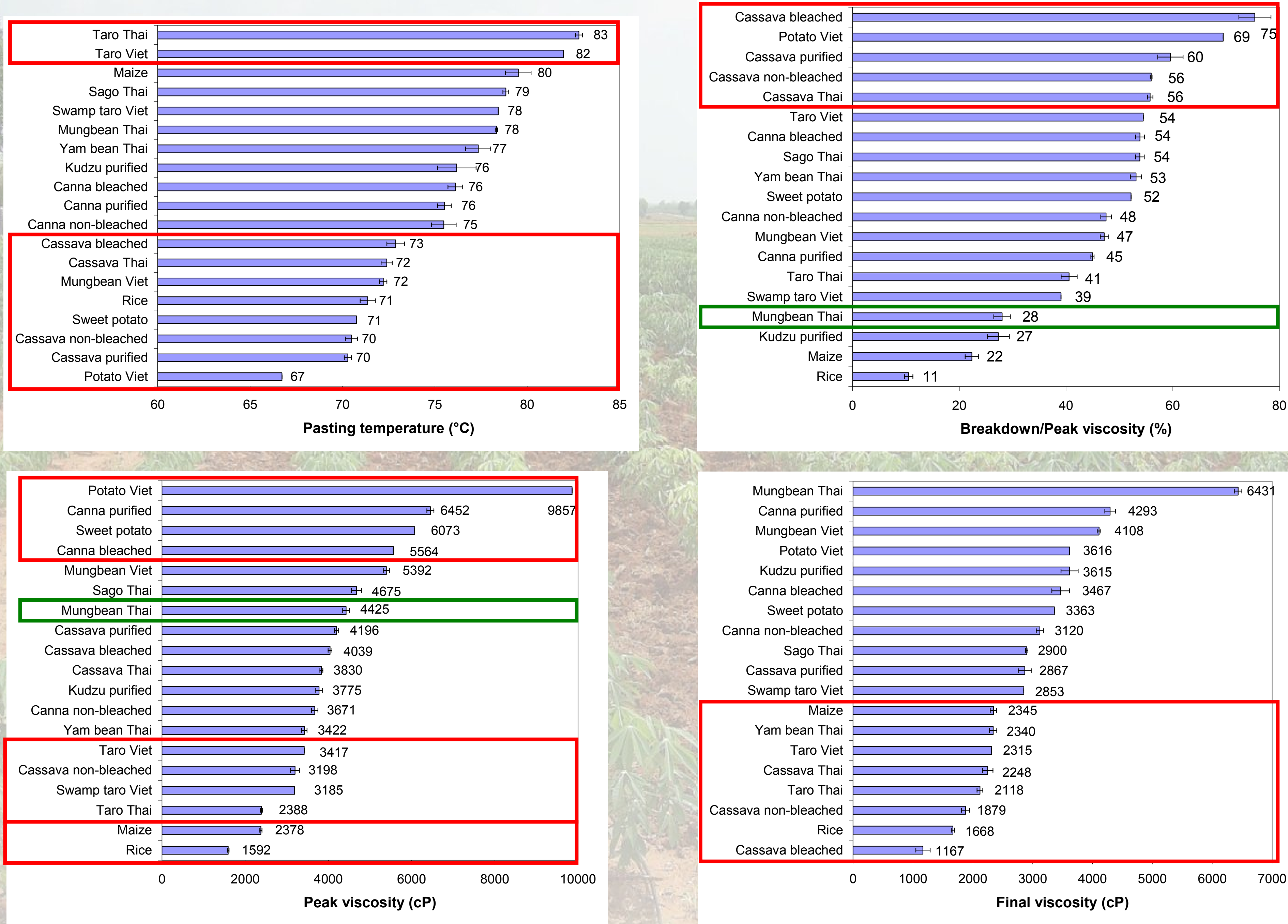
A- and B-type retrogradation domains

Source: Dr I. Farhat, Nottingham University (UK)



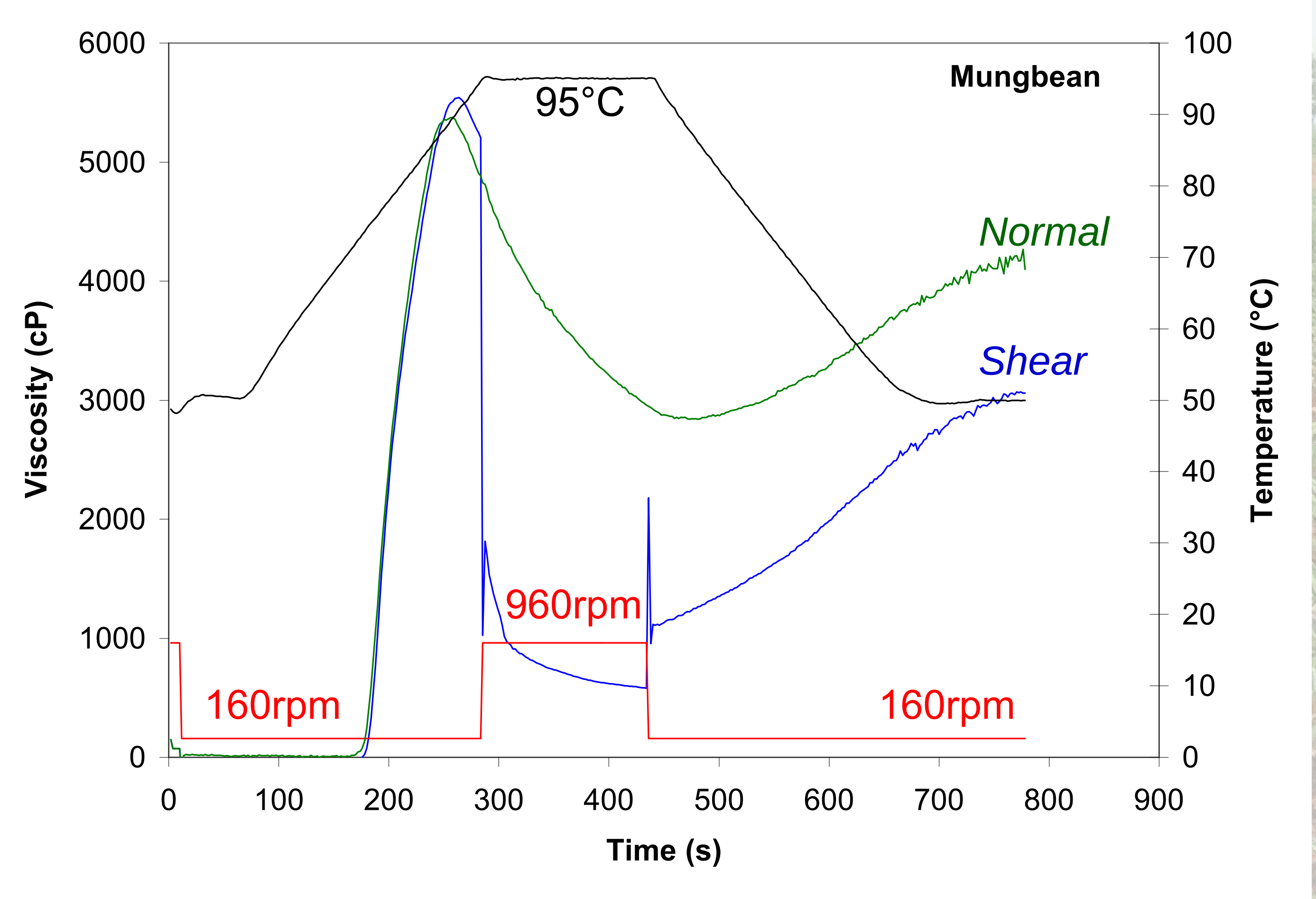
RVA profiles





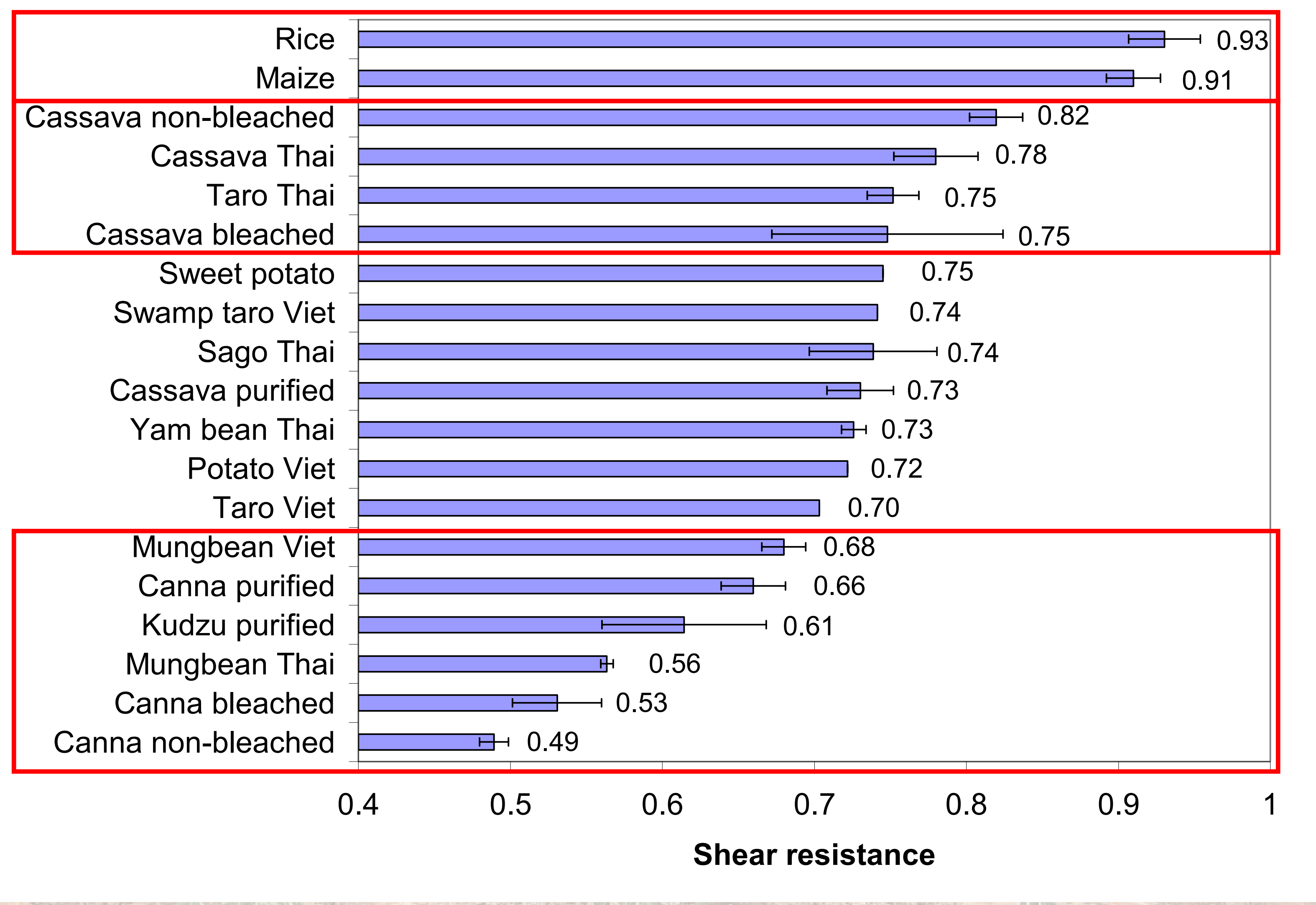
Taro Thai 83
Taro Viet 82
Maize 80
Sago Thai 79
Swamp taro Viet 78
Mungbean Thai 78
Yam bean Thai 77
Kudzu purified 76
Canna bleached 76
Canna purified 76
Canna non-bleached 75
Cassava bleached 73
Cassava Thai 72
Mungbean Viet 72
Rice 71
Sweet potato 71
Cassava non-bleached 70
Cassava purified 70
Potato Viet 67
60 65 70 75 80 85
Pasting temperature (°C)
Cassava bleached 75
Potato Viet 69
Cassava purified 60
Cassava non-bleached 56
Cassava Thai 56
Taro Viet 54
Canna bleached 54
Sago Thai 54
Yam bean Thai 53
Sweet potato 52
Canna non-bleached 48
Mungbean Viet 47
Canna purified 45
Taro Thai 41
Swamp taro Viet 39
Mungbean Thai 28
Kudzu purified 27
Maize 22
Rice 11
0 20 40 60 80
Breakdown/Peak viscosity (%)
Potato Viet 9857
Canna purified 6452
Sweet potato 6073
Canna bleached 5564
Mungbean Viet 5392
Sago Thai 4675
Mungbean Thai 4425
Cassava purified 4196
Cassava bleached 4039
Cassava Thai 3830
Kudzu purified 3775
Canna non-bleached 3671
Yam bean Thai 3422
Taro Viet 3417
Cassava non-bleached 3198
Swamp taro Viet 3185
Taro Thai 2388
Maize 2378
Rice 1592
0 2000 4000 6000 8000 10000
Peak viscosity (cP)
Mungbean Thai 6431
Canna purified 4293
Mungbean Viet 4108
Potato Viet 3616
Kudzu purified 3615
Canna bleached 3467
Sweet potato 3363
Canna non-bleached 3120
Sago Thai 2900
Cassava purified 2867
Swamp taro Viet 2853
Maize 2345
Yam bean Thai 2340
Taro Viet 2315
Cassava Thai 2248
Taro Thai 2118
Cassava non-bleached 1879
Rice 1668
Cassava bleached 1167
0 1000 2000 3000 4000 5000 6000 7000
Final viscosity (cP)

Shear resistance



Stir at 960rpm during the 95°C phase of the profile (Mestres et al, 1997).

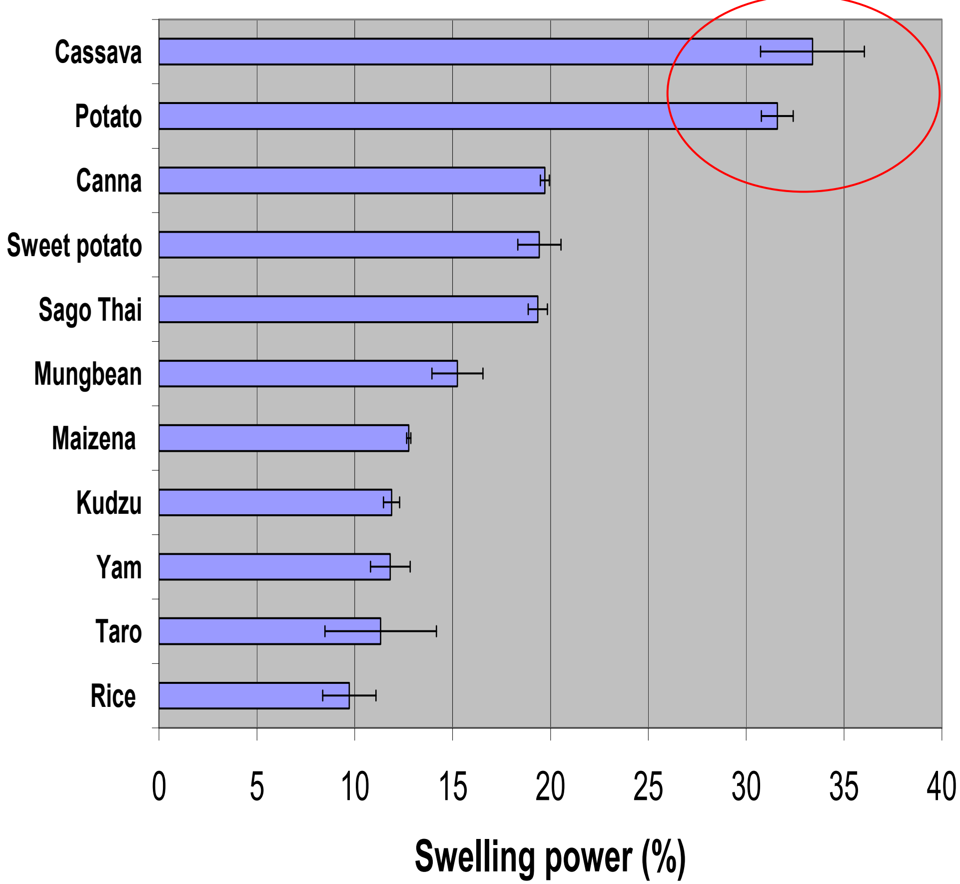
Shear resistance

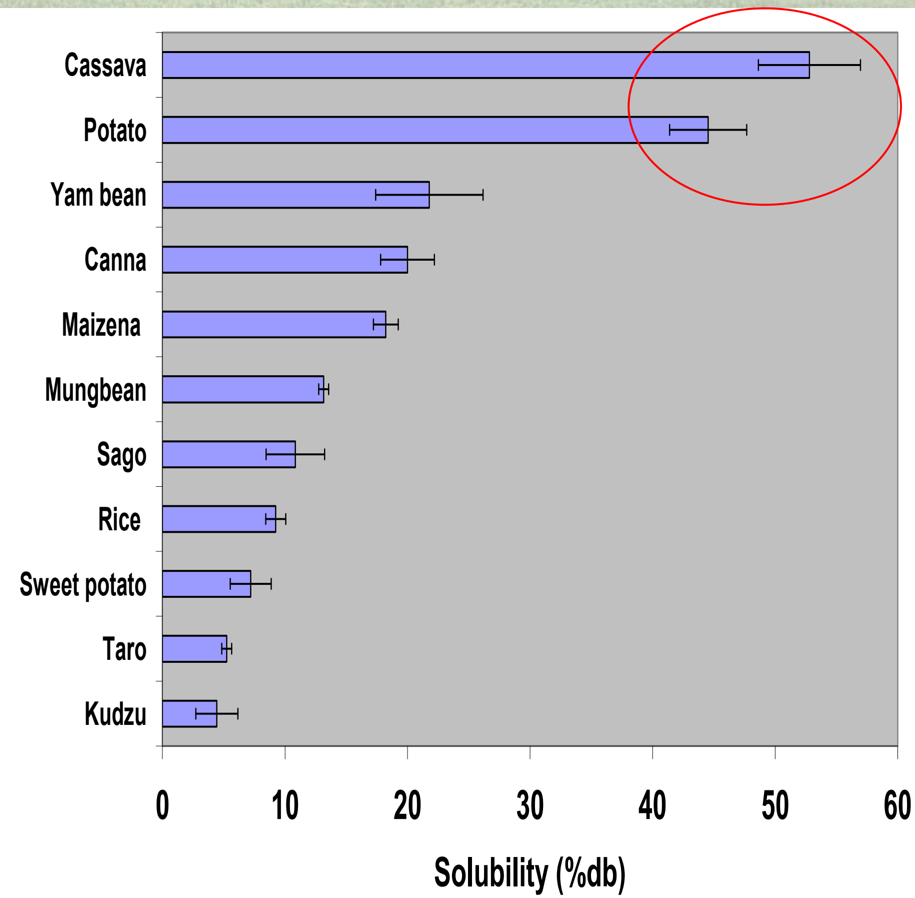


Shear resistance = FV(shear) / FV(normal)

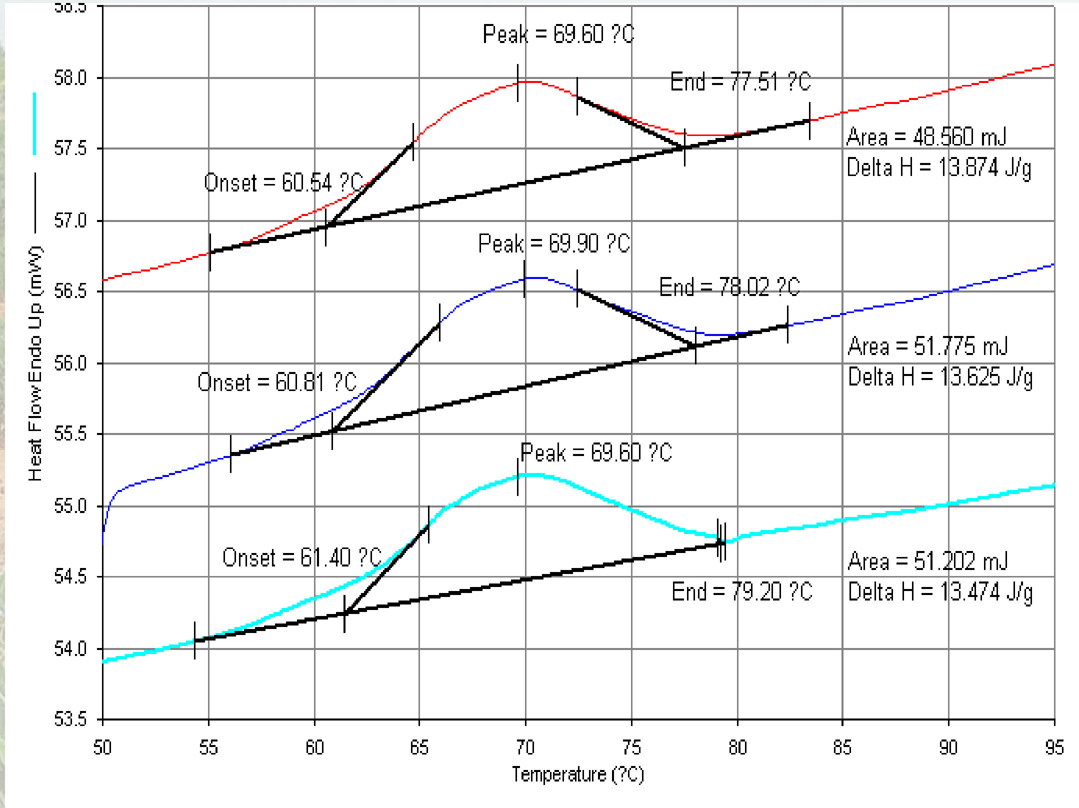
Swelling power (SP) and solubility (SLB)

0.1 g of starch in 25 mL of distilled water. Heating and stirring (160rpm) by RVA for 30 min **at 70°C**. Centrifugation at 2000 rpm => collection and weighing of supernatant + precipitate (Mestres et al, 2005)



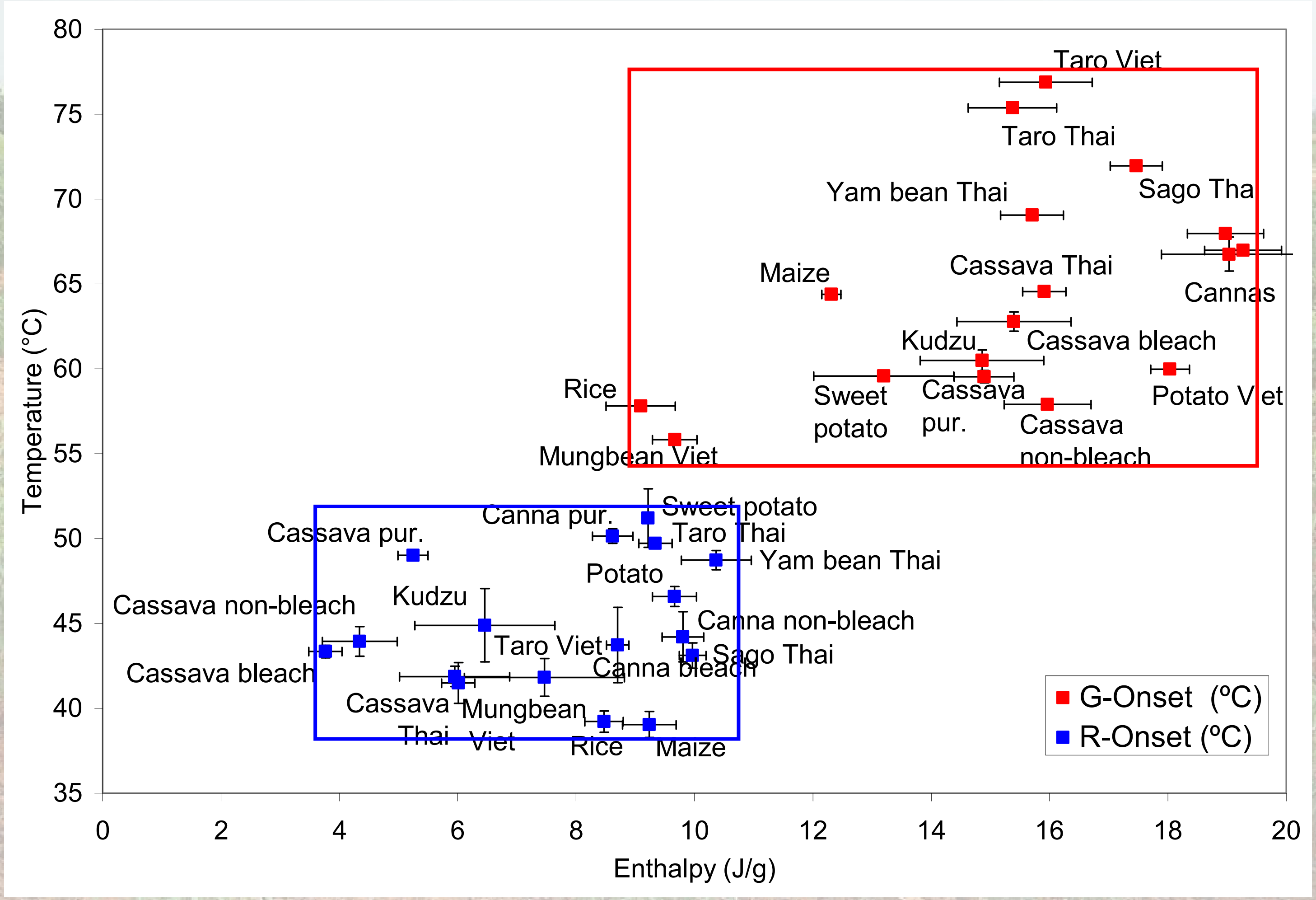


Gelatinization & retrogradation (DSC)



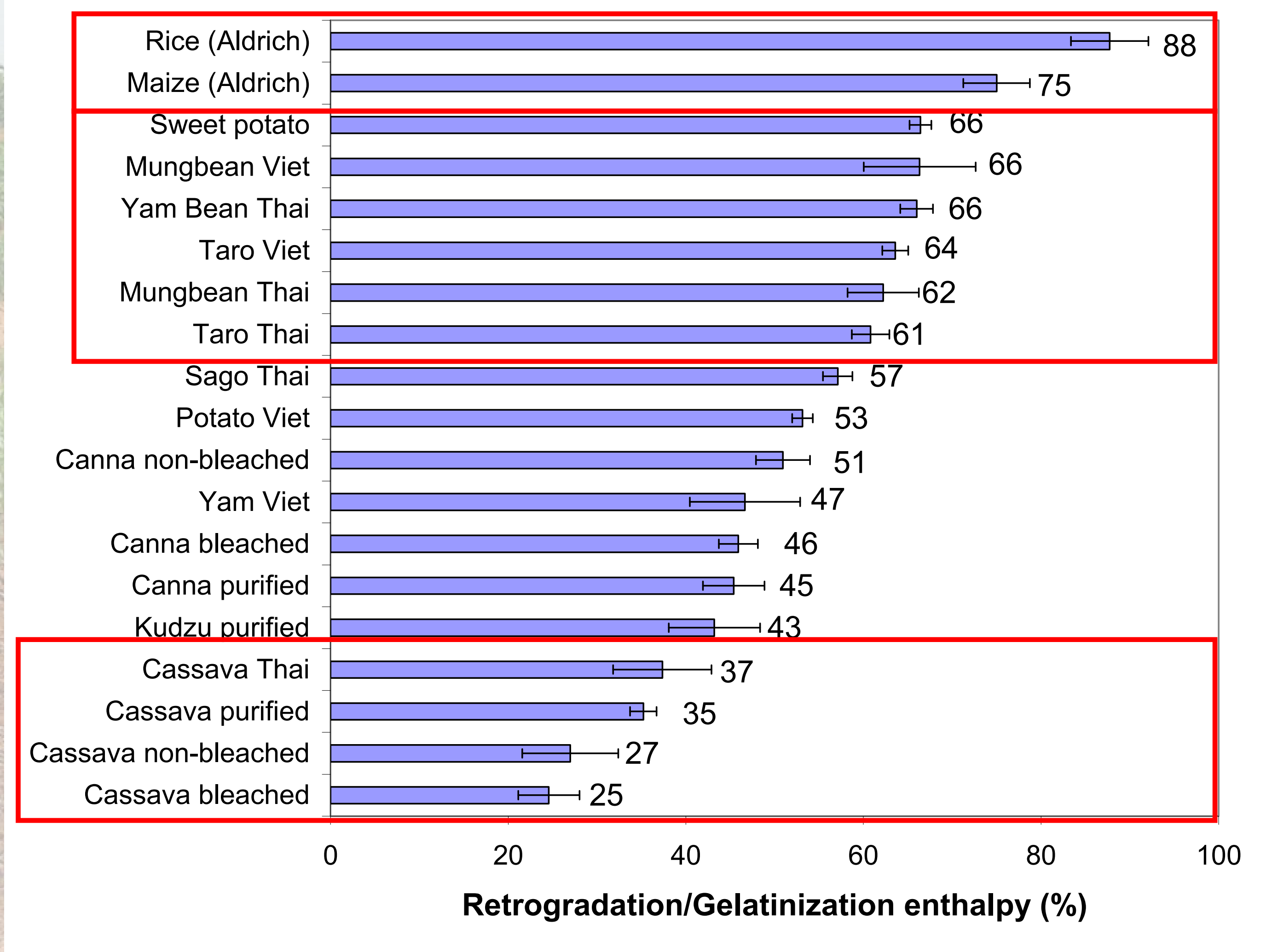
- Gelatinization in excess water (25% starch).
- Retrogradation after 15 days at 4°C.

Gelatinization & retrogradation (DSC)



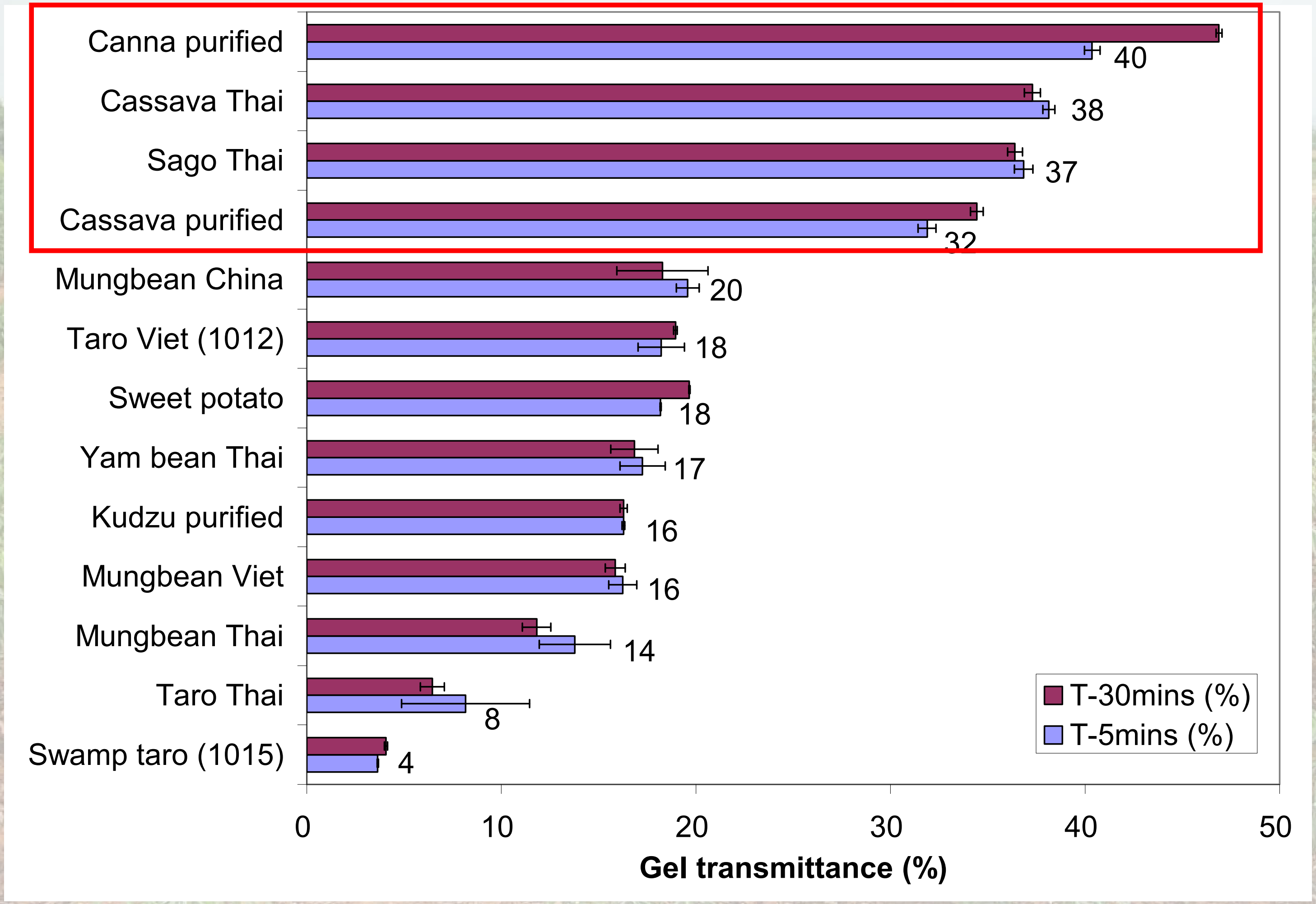
- Gelatinization range: 56-77°C; 9-19 J/g.
- Retrogradation range: 39-51°C; 4-10 J/g.

Retrogradation tendency



% Retrog. = $\Delta H(\text{Retrogradation}) / \Delta H(\text{Gelatinization})$

Gel clarity



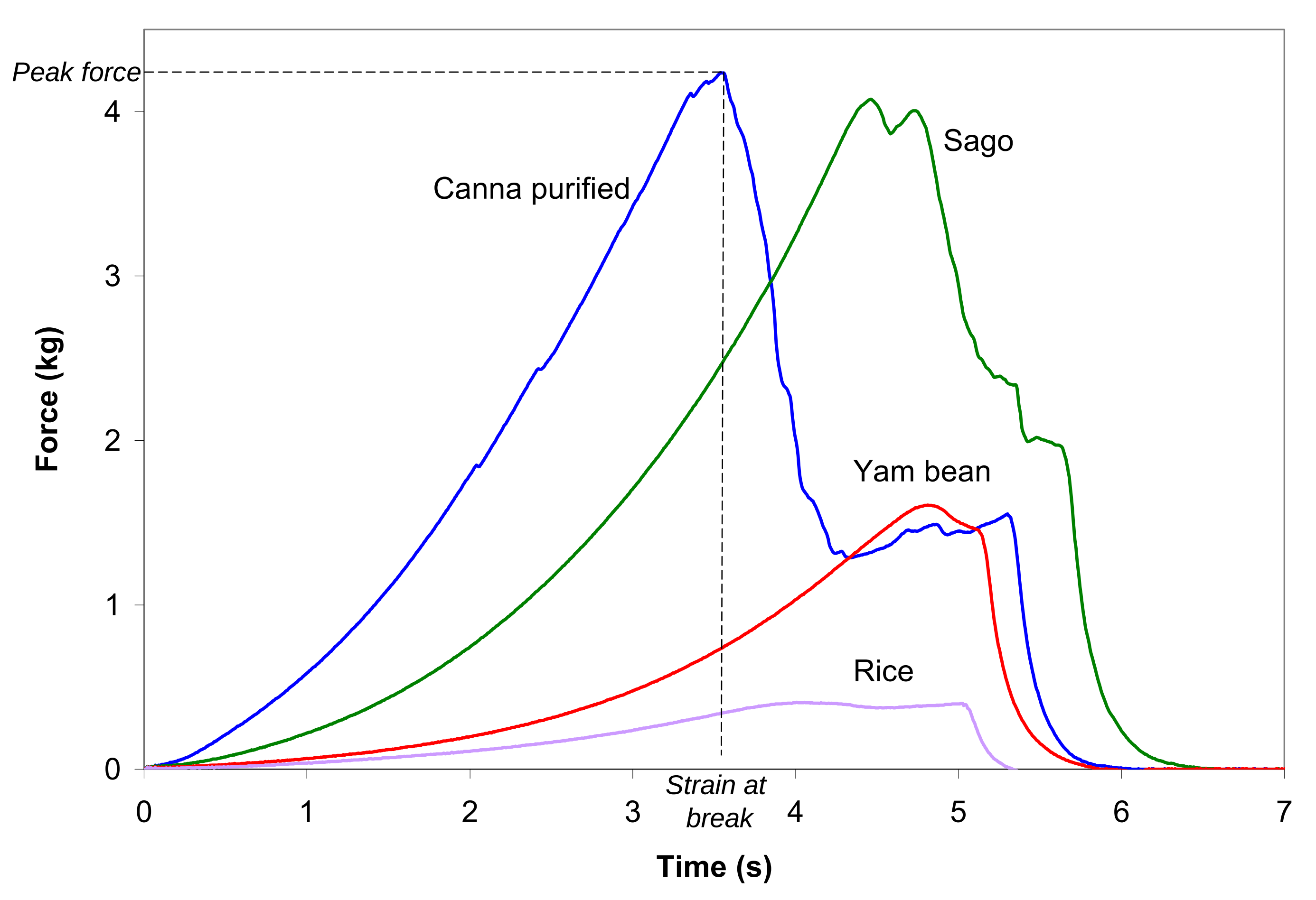
- Method: Transmittance at 650nm of 1% starch pastes (Craig et al., 1989)
- Taros may not be fully gelatinized

Gel texture

Starch gels (10.3%) prepared by RVA and stored at 4°C for 13 days.

Dimensions:
Diameter 36mm
Height 20.5mm

Gel texture

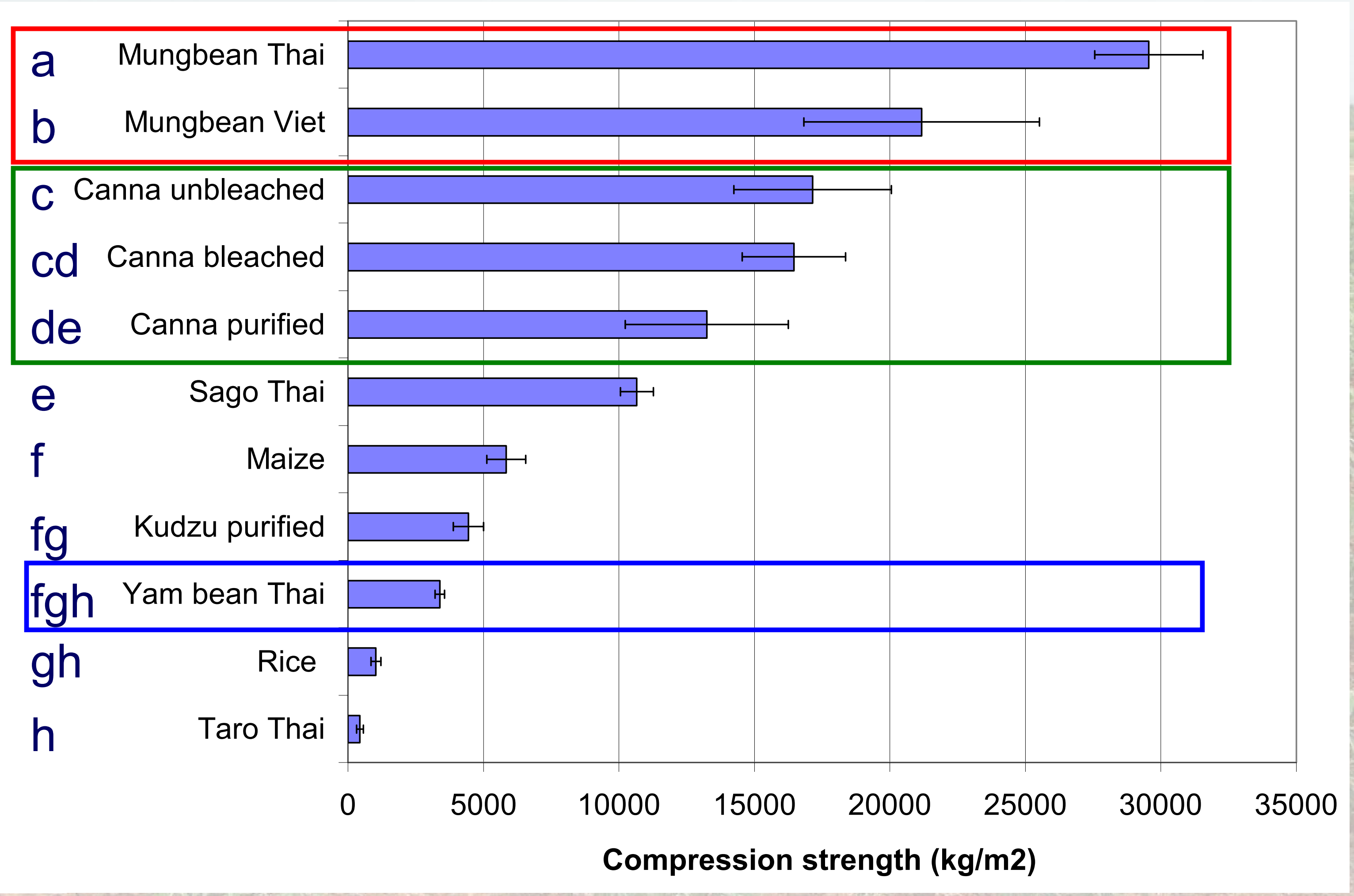


Record:
- Peak force (kg)
- Deformation at peak force (mm)

Normalized to:
- Compression strength (kg/m2)
- Strain at break

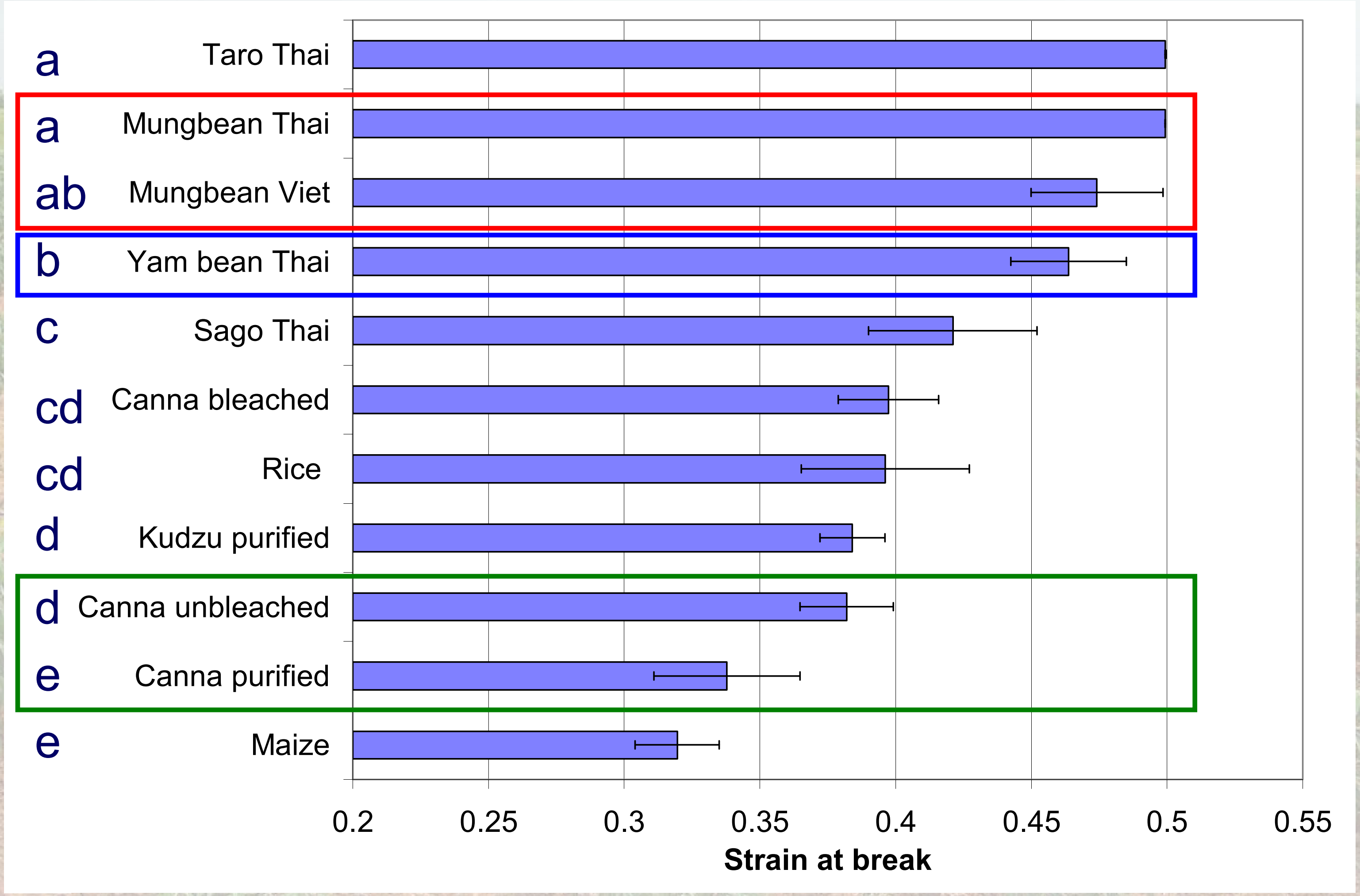
Compression: 2mm/s
Target strain: 50% of initial height (~10mm)
3 replications per gel

Gel texture – Compression strength



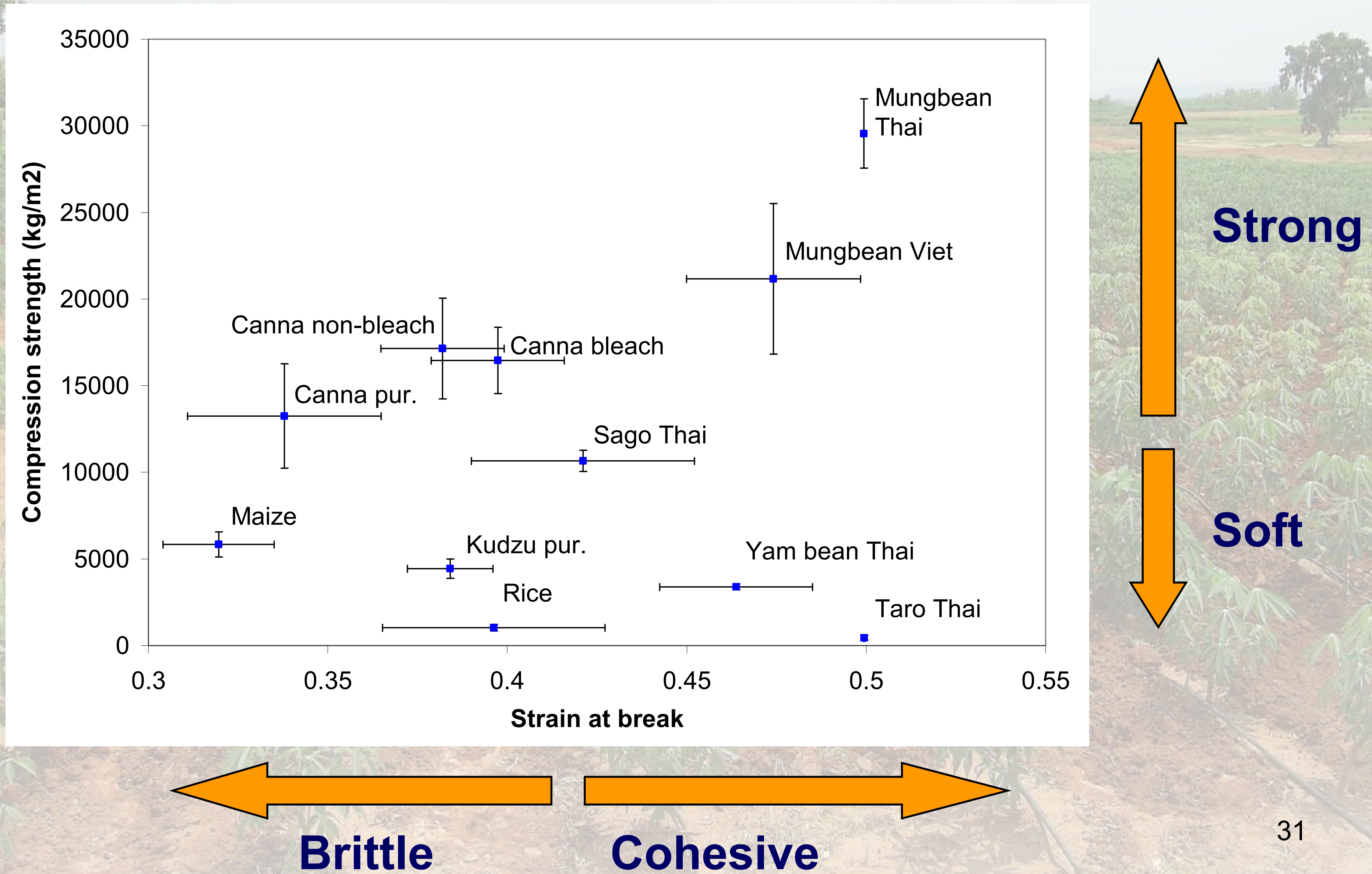
Letters indicate statistically significant differences (LSD Fisher test; $p<0.05$)

Gel texture – Strain at break



Letters indicate statistically significant differences (LSD Fisher test; $p<0.05$)

Gel texture



Compression strength (kg/m2)
35000
30000
25000
20000
15000
10000
5000
0
0.3
0.35
0.4
0.45
0.5
0.55
Strain at break
Mungbean Thai
Mungbean Viet
Canna non-bleach
Canna bleach
Canna pur.
Sago Thai
Maize
Kudzu pur.
Rice
Yam bean Thai
Taro Thai
Strong
Soft
Brittle
Cohesive

Noodle texture

Starch mixed with water and worked into a dough (partially gelatinized).

Flat noodles prepared with a Marcato 150 pasta machine.

Dimensions:
Cross section 9x2mm (after cooking)
Length 150mm

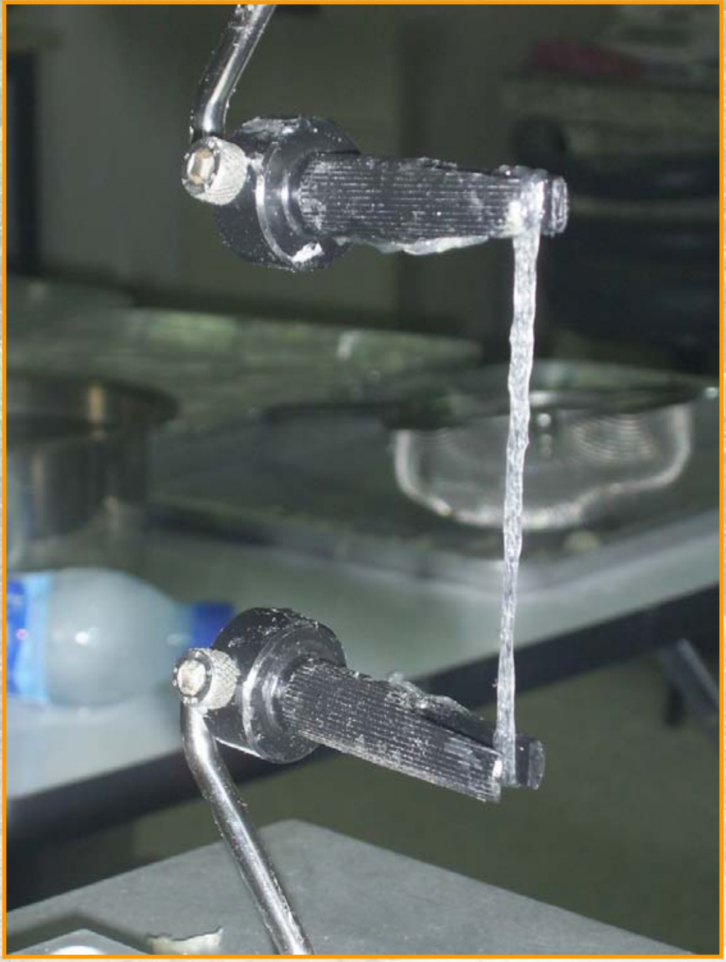
Moisture content ~75-80% (after cooking)

Noodle texture

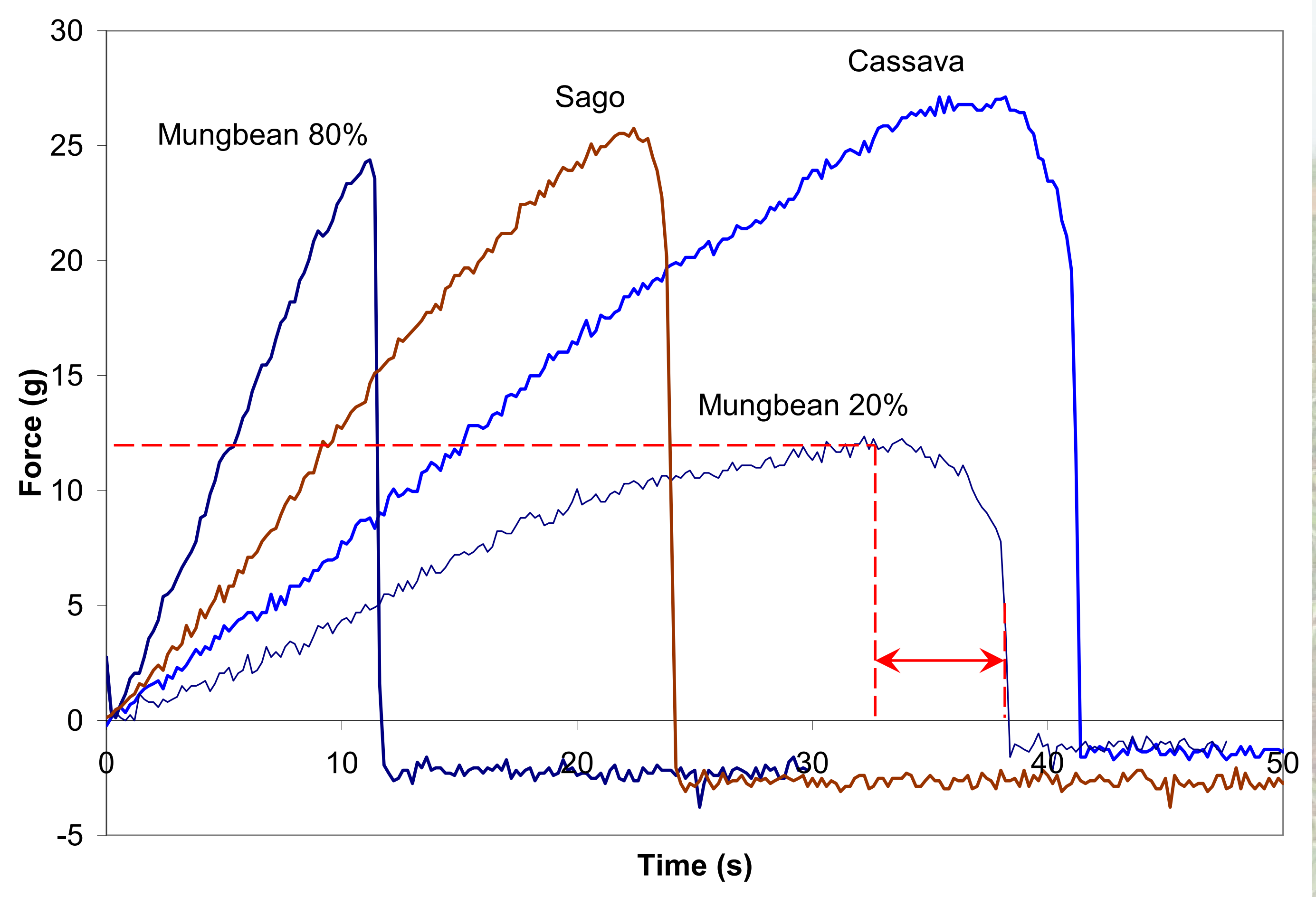
Noodle texture

Noodles tested in extension with texture analyzer

- Noodles made of pure starches
- Blends of cassava and other starches



Noodle texture

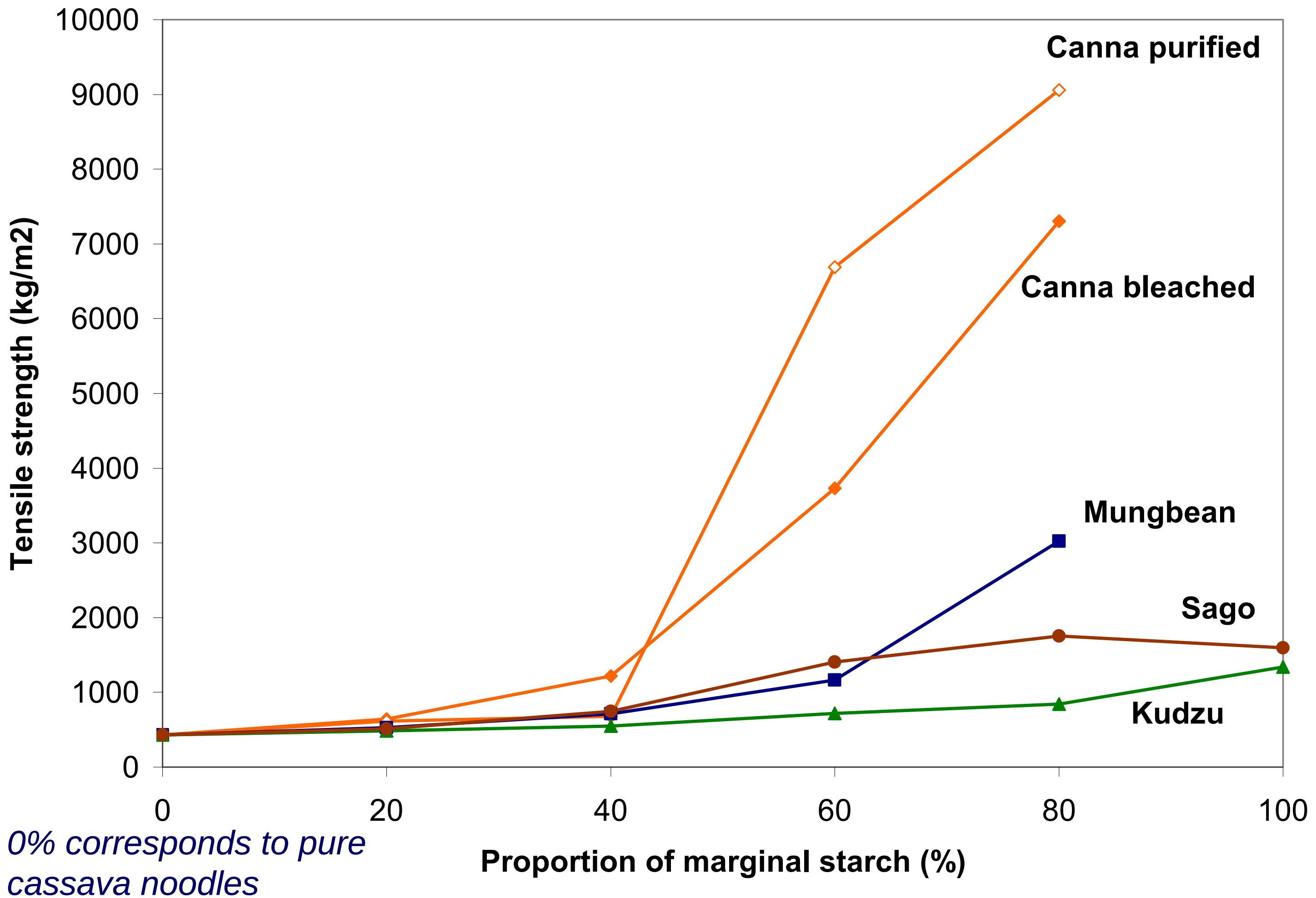


Extension speed: 2mm/s
Distance: 10-30cm until break
Initial length: 50mm
15-20 replications/sample

Record:
- Peak force (g)
- Deformation at peak force (mm)
- Deformation at final break (mm)

Normalized to:
- Tensile strength (kg/m2)
- Strain at peak force
- Additional strain at break

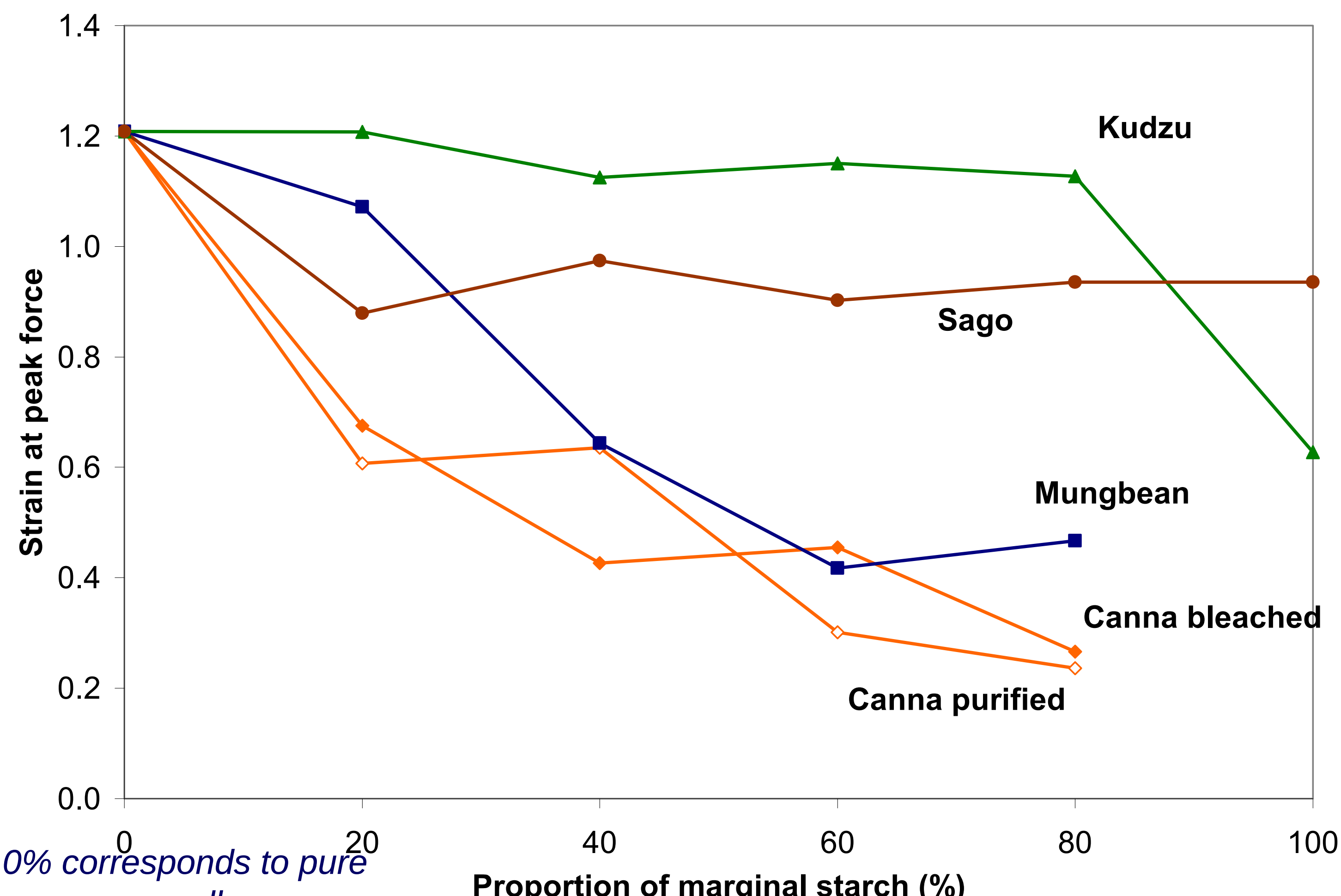
Noodle texture



0% corresponds to pure cassava noodles

Above 40%, tensile strength moves towards that of the corresponding pure starch.

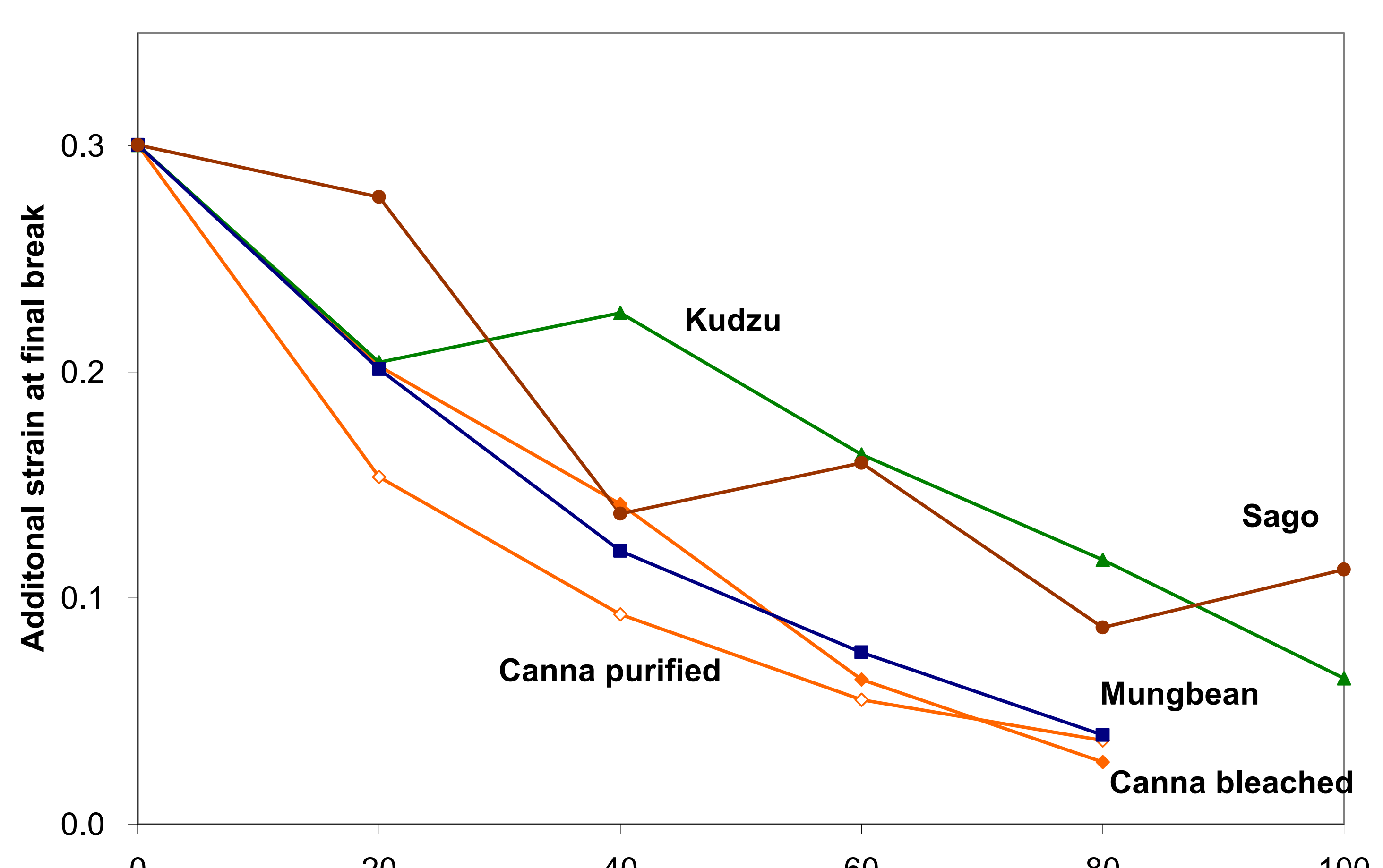
Noodle texture



0% corresponds to pure cassava noodles

Kudzu: Cassava determines extension behaviour up to 80% kudzu.
Sago: Cassava determines extension behaviour only up to 20%.
Extension behaviour of **mungbean** and **canna** is determined by both components.
→ Hypothesis of different blend morphologies between different types of starches.

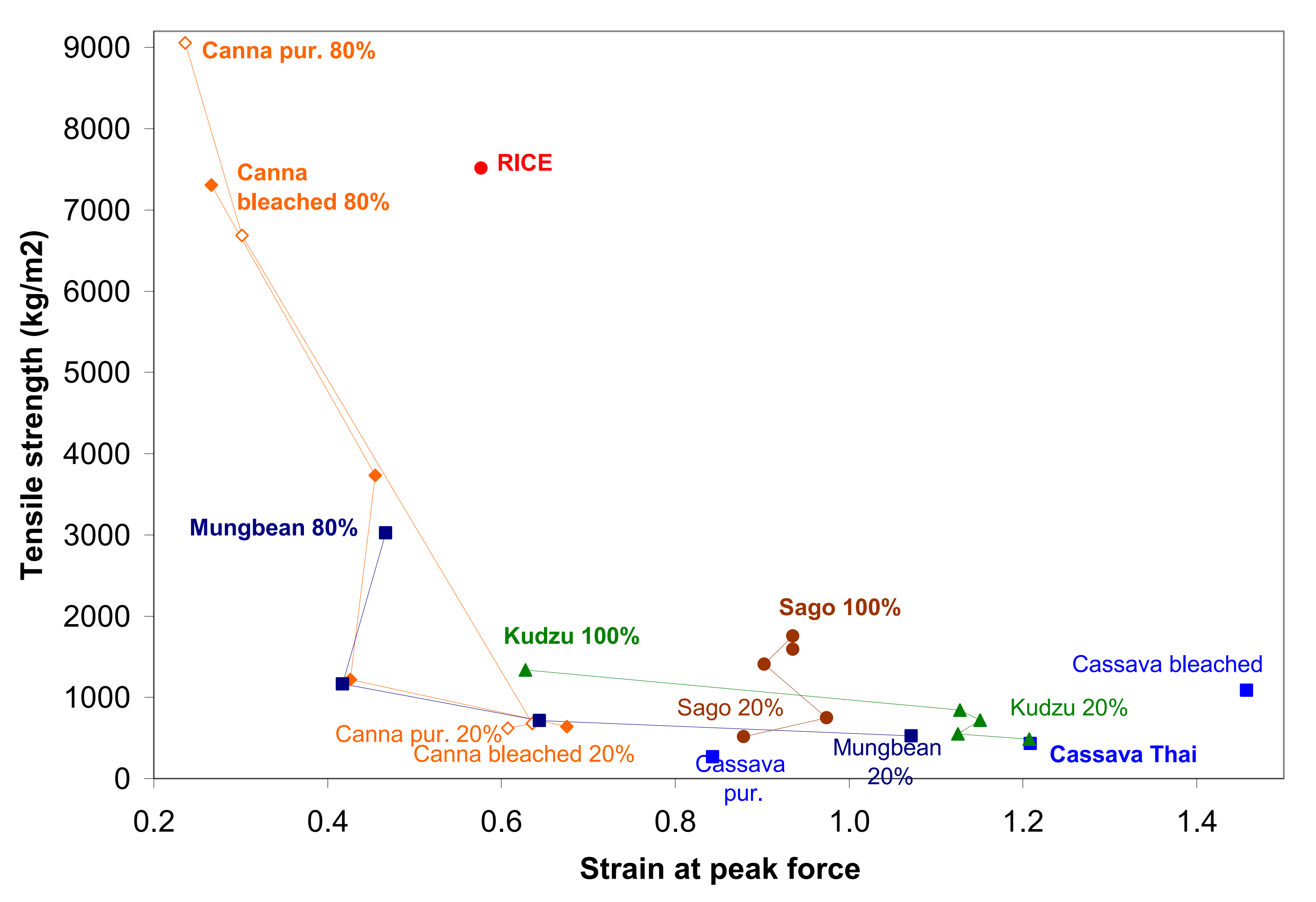
Noodle texture



0% corresponds to pure cassava noodles

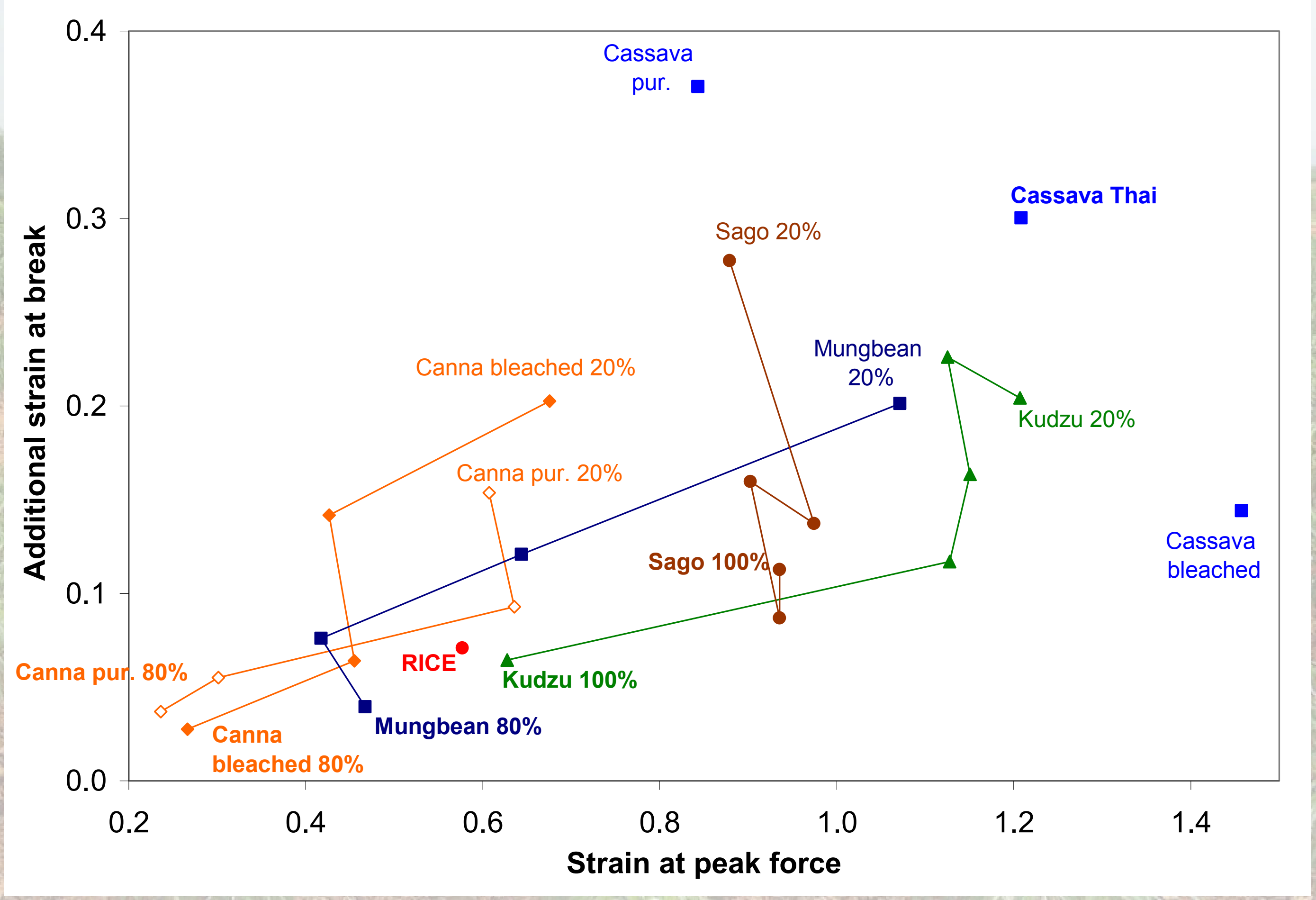
Cassava gives the most extensible noodles both at peak force and final break. Addition of other starches reduces the strain at final break.

Noodle texture



Canna, mungbean: Strong texture, low extensibility.
Cassava, sago: Soft, extensible texture.
Kudzu: Soft texture with low extensibility.

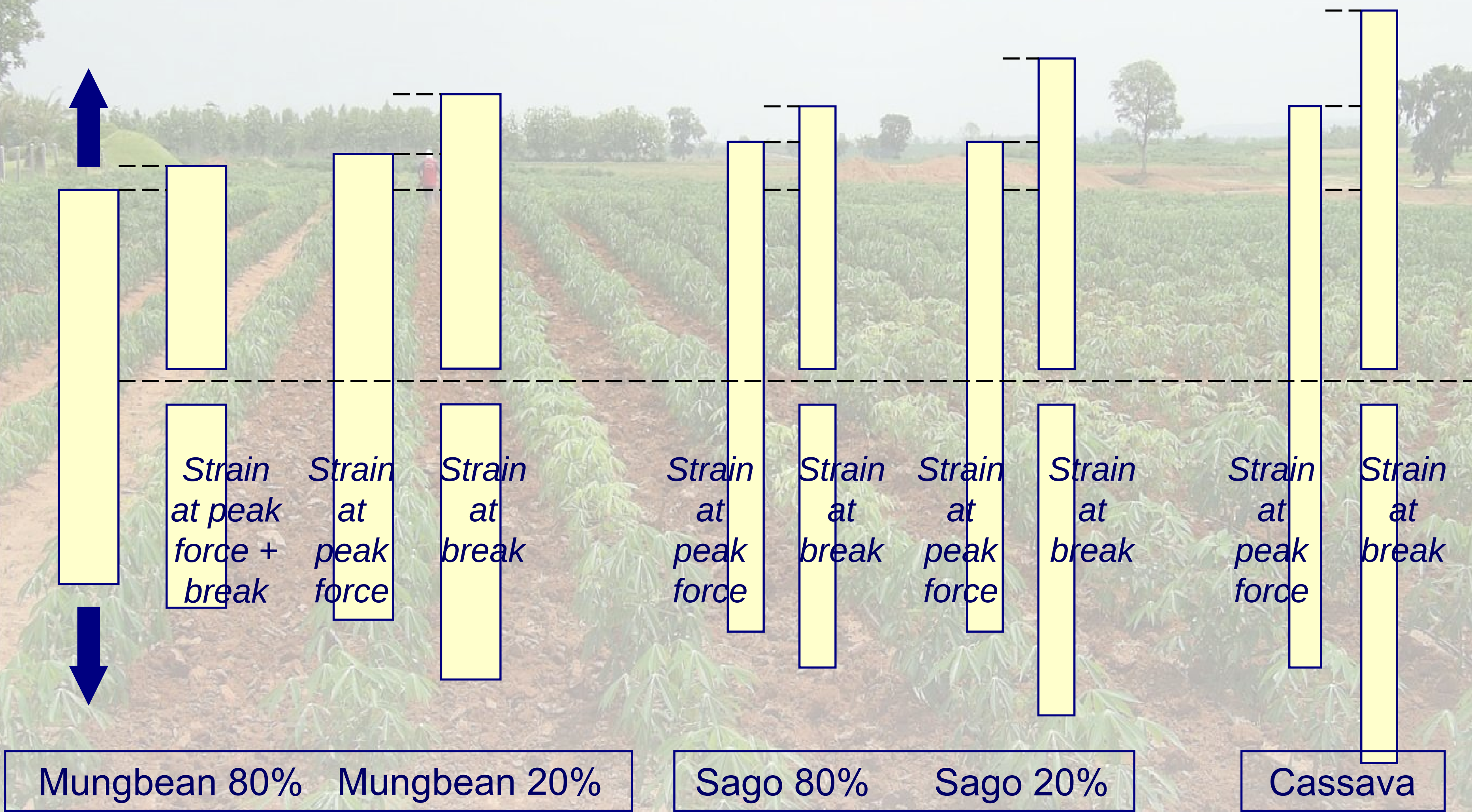
Noodle texture



Kudzu, sago: Strain at peak force varies little, contrary to strain at break → Kudzu/sago determine strain at peak; cassava determines break behavior → Hypothesis of poor blend with cassava starch.

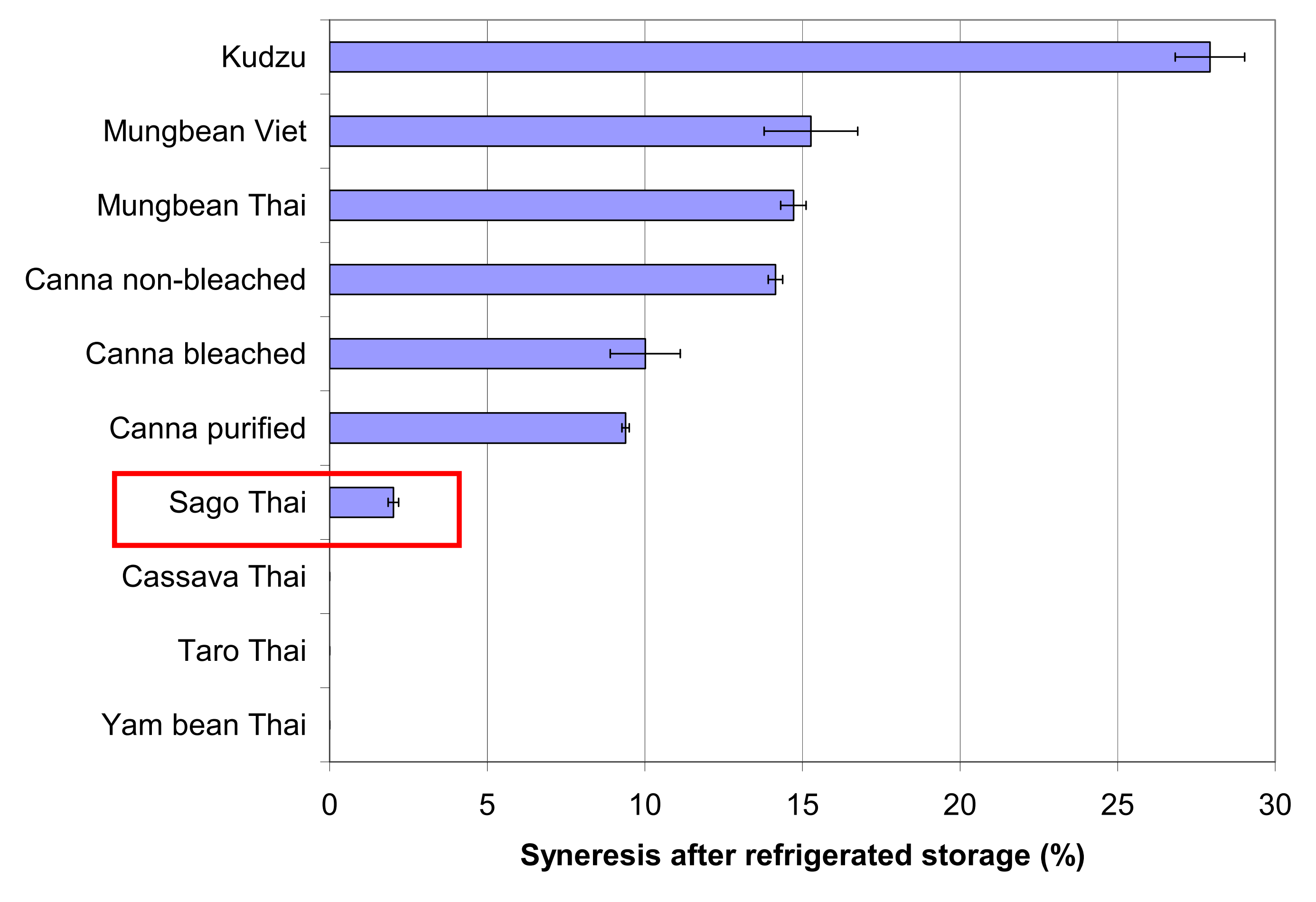
Canna, mungbean: Strain at peak force and additional strain at final break vary simultaneously → Hypothesis of good blend with cassava starch.

Noodle texture



Mungbean: Extends little, breaks quickly.
Sago: Extends well, breaks; extends more if cassava added.
Cassava: Extends a lot, starts to break, extends more before complete break.

Syneresis - refrigerated



10% starch gels.

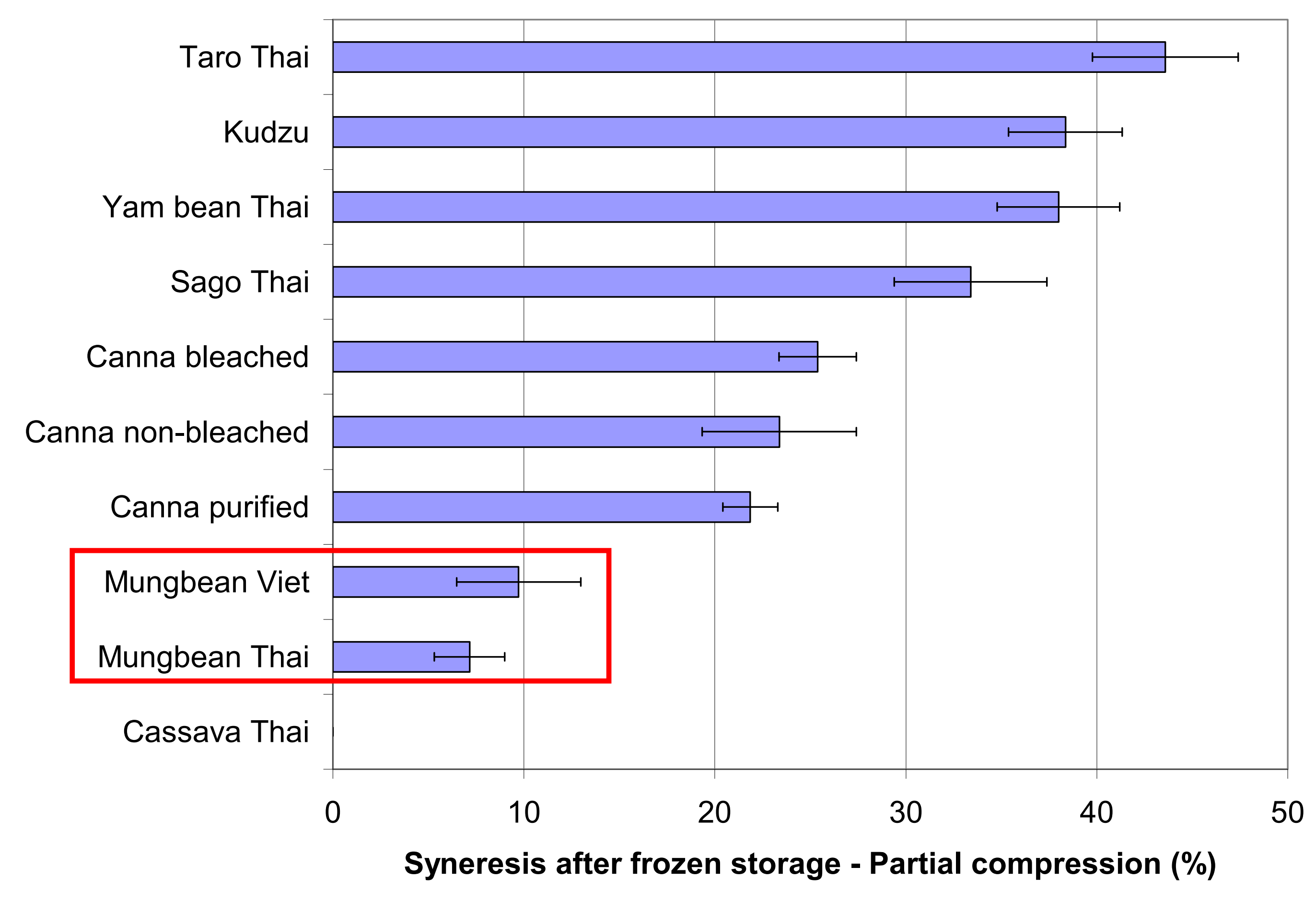
Storage 10 days at 4°C.

The syneresis was calculated as the difference in gel weight before and after storage, and expressed as % of the initial weight.

Sago starch gels had the best stability under refrigerated conditions (syneresis below 2%).

Cassava, taro, yam bean did not gel.
Kudzu is paste-like more than gel-like and did not retain water well.

Syneresis – frozen – Partial compression



10% starch gels.

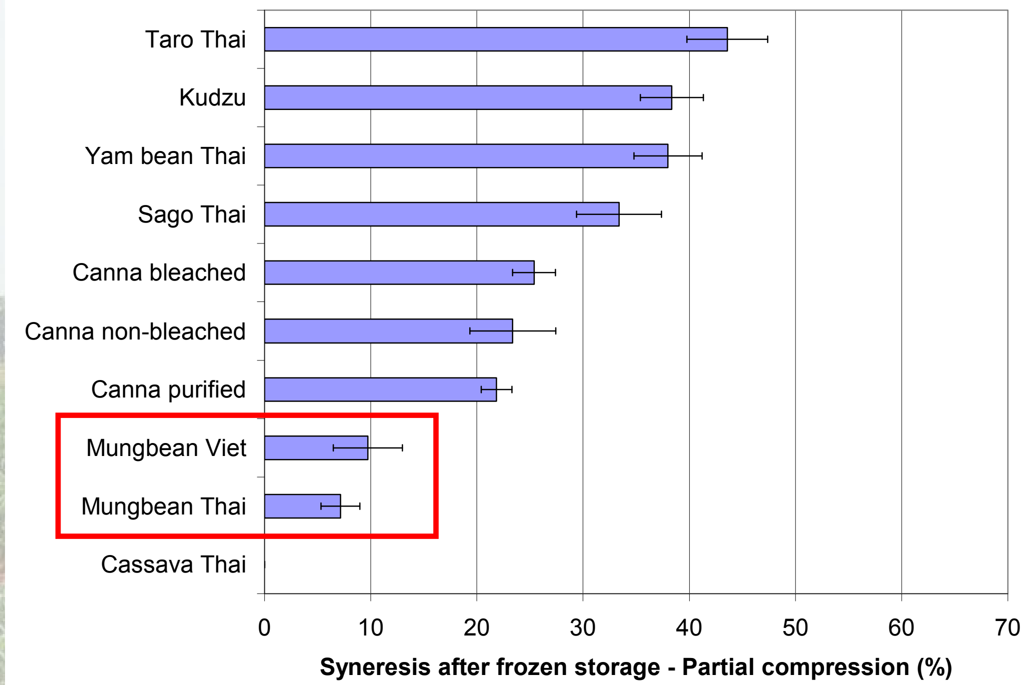
Five freeze-thaw cycles between -20°C and 25°C.

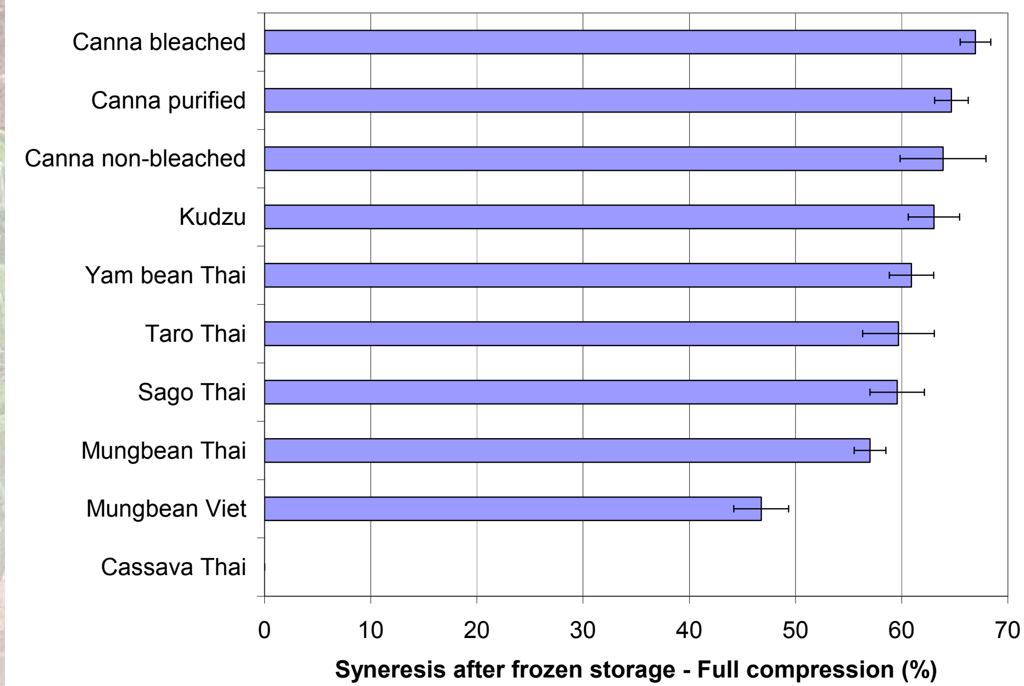
The syneresis was calculated as the difference in gel weight before storage and after compression, and expressed as % of the initial weight.

Mungbean and canna starch gels were most efficient for retaining water (7-9% and 22-25% syneresis respectively), possibly due to their higher gel strength (less deformation).

Syneresis – frozen – Full compression

Differences between starches disappeared after full compression, indicating that the water retention after freezing may be determined mainly by the gels resistance to mechanical deformation.





Correlations between starch properties

Variable	GS-D[4,3]	AC	PaTc	PaTi	PkV	HS	FV	BD	SLB	SP70	TGo	delH	TRo	RdelH	R/G	Lipi
GS-D[4,3]																
AC	0,71															
PaTc	-0,29	-0,31														
PaTi	-0,28	-0,30	1,00													
PkV	0,48	0,37	-0,67	-0,66												
HS	0,29	0,49	-0,41	-0,41	0,76											
FV	0,37	0,62	-0,32	-0,32	0,62	0,91										
BD	0,50	0,27	-0,69	-0,68	0,97	0,57	0,42									
SLB	0,07	-0,06	-0,59	-0,59	0,10	-0,37	-0,41	0,27								
SP70	0,12	-0,03	-0,65	-0,65	0,19	-0,27	-0,25	0,35	0,86							
TGo	-0,04	-0,30	0,86	0,86	-0,43	-0,48	-0,46	-0,35	-0,36	-0,41						
delH	0,52	-0,05	0,10	0,12	0,02	-0,32	-0,38	0,16	0,24	0,21	0,41					
TRo	-0,26	-0,59	0,10	0,10	0,07	-0,01	-0,08	0,09	-0,27	-0,03	0,17	0,00				
RdelH	0,34	0,00	0,48	0,49	0,10	0,02	-0,00	0,12	-0,46	-0,45	0,69	0,48	0,21			
R/G	0,01	0,10	0,41	0,41	0,11	0,28	0,31	0,03	-0,67	-0,65	0,40	-0,27	0,17	0,71		
Lipi	0,26	0,34	-0,40	-0,41	0,03	0,29	0,48	-0,07	-0,05	0,14	-0,62	-0,22	0,02	-0,41	-0,26	

Significant correlations at p<0.01

- Granules size <-> Higher peak viscosity & Lower shear resistance
- High AM <-> Higher final viscosity; Increased gel hardness (?)
- Higher pasting time <-> Higher DSC onset temperature
- Higher swelling power <-> Higher breakdown

Conclusions (1)

	Mungbean	Canna	Sago	Kudzu	Yam bean	Taro	Cassava
Granule size:	+	+++	++	--	--	---	-
Amylose:	+++	++	+	-	-	--	-
RVA:							
Pasting temp.	--	+	++	+	+	+++	---
Peak viscosity	++	+++	+	--		---	--
Breakdown (rel.)	--	+	++	---	++	--	+++
Final viscosity	+++	++	+	++	--	--	---
Shear resistance	--	---	++	--	++	+	+++
DSC:							
Gelat. onset	--	+	++	-	+	+++	---
Gelat. enthalpy	--	+++	++	-	+	-	++
% Retrogradation	++	-	+	--	++	+	---

Conclusions (2)

	Mungbean	Canna	Sago	Kudzu	Yam bean	Taro	Cassava
Gels:							
Clarity	-	++	++	-	-	--	++
Strong, cohesive	++	-	+	-	-	-	-
Strong, brittle	-	++	+	-	-	-	-
Soft, cohesive	-	-	+	-	++	-	-
Soft, brittle	-	-	+	++	-	-	-
Noodles:							
Rigid	++	+++	-	-	n/a	n/a	-
Extensible	-	-	++	+	n/a	n/a	+++
Noodle blends with cassava:							
Rigid	++	+++	-	-	n/a	n/a	n/a
Extensible	-	-	++	+++	n/a	n/a	n/a
Syneresis:							
Refrigerated	-	+	+++	-	n/a	n/a	n/a
Frozen	++	+	-	-	-	-	n/a

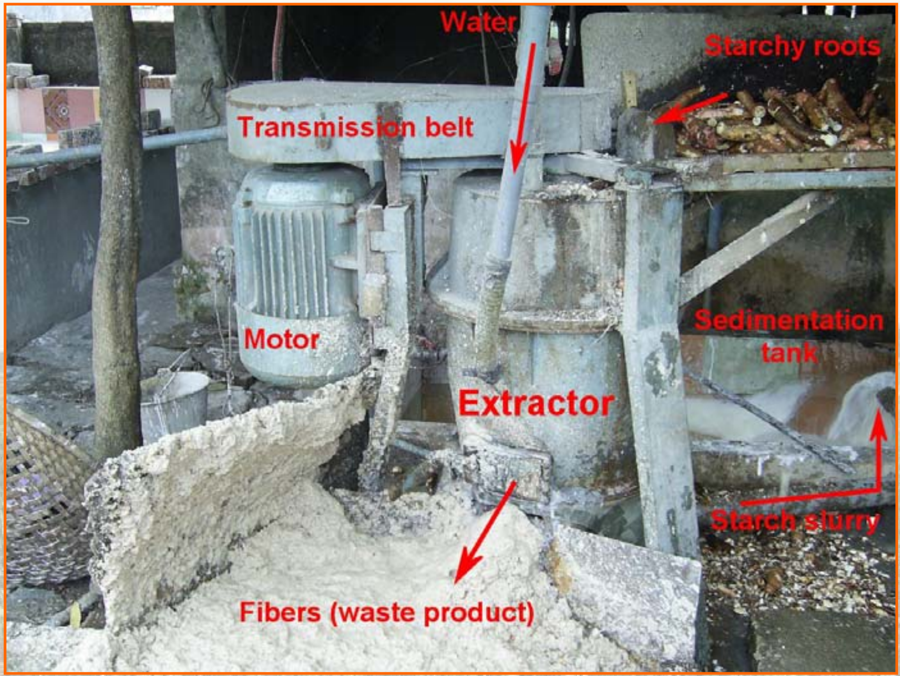
<u>Steps to industrial production</u>

<u>Quantities:</u>
Cassava factory: ~800 tons roots/day (Thailand)
Canna, kudzu: 1-2 tons roots/day (Vietnam)
Mungbean: est. 1 ton beans/day (?)
Sago: Household scale
→ Niche applications first, then scaling-up.

<u>Technology and quality control:</u> To be adapted from established starch production process (canna, tapioca → CSTRU).

<u>Funding:</u> If interest for buying the starch, investment possible by Thai company; or support by BOI for FDI.

Cassava 500-800 t roots/day



Canna 1-2 t roots/day

Sago

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Conference announcement

STARCH UPDATE 2009

Bangkok, 24-25 September 2009

→ Starch properties and technology
→ Bio-ethanol
→ Bio-plastics
→ Study tour to Sonish cassava starch factory and Double A paper factory

http://www.biotec.or.th/StarchUpdate2009/

Thank you for your attention!